SCIENTIFIC AMERICAN SUPPLEMENT

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VOLUME LXXIV] NUMBER 1920 NEW YORK, OCTOBER 19, 1912 [10 CENTS A COPY $5.00 A YEAR

The New Willamette River Railway Bridge, Portland, Oregon*

THE Oregon-Washington Railroad and Navigation Company has about completed its new lift bridge across the Willamette River at Portland, Ore. This bridge, when finished, will have cost $1,715,000, and is located about 700 feet up stream from the present bridge which it is to replace. The structure provides for two decks, a lower deck for a double track railway and an upper deck for street railway and highway traffic.

The channel is crossed by three spans, two fixed spans of 287 feet each, flared at the shore ends to provide for curvature of the railway tracks, and a center vertical lift span 220 feet long. At the east end is a highway viaduct approach 305 feet long, and on the west end a highway approach 512 feet long.

The vertical lift span provides for a railway deck having an independent vertical lift movement of 46 feet. This feature is accomplished by supporting the railway floor system and lateral truss on hanger posts from the upper movable span. Each hanger is connected to four cables, and is constrained to move vertically inside the corresponding vertical posts of the upper movable span.

Both the railway deck and upper movable span are counter-balanced with concrete weights; there are two of these weights for the movable span weighing 866 tons each. For the lower, or railway deck, there are eight counter-weights, four on a side; the four weighing 212 tons.

The maximum vertical clearance for both decks will be 164 feet above low water. The maximum independent clearance of the railway deck will be 72 feet above low water. This clearance given by the railway deck will be sufficient to allow the passage of nearly all river traffic without disturbing the position of the upper span for highway service. River traffic under the old bridge requires as many as 134 openings in 24 hours, with an average of about 70 openings per day for the entire year.

* From the *Railway Age Gazette*.

The tonnage in the new bridge is as follows:

	Tons.
East highway approach	399.8
West highway approach	687
Four 80-foot deck railway girders	103
East riveted span	2,230
West riveted span	1,948
Lift span with lifting deck	1,594
Towers	799
Trolley poles, handrail, gas-pipes, etc.	342
Machinery and motors	484
Total tonnage	8,686.8

The steel was delivered at the east of the bridge site in a temporary storage yard. Construction tracks were laid both on the east and west sides of the river, so that cars could be spotted conveniently for raising derricks.

The viaducts were raised with two 30-ton skid derricks, using a 45-foot boom, one derrick for each side of the river. This apparatus placed the upper floor system and laterals for the fixed spans and the lower members of the towers. Their heaviest lift was a 29-ton upper floor beam.

The fixed spans were erected on falsework, using double bents, with 22 piles. Raising and placing the truss members and lower floor was accomplished by a scow derrick, with 110-foot sheer legs, constructed from four piles. A 54-ton top chord section was placed with this.

It was decided to erect the vertical lift span and railway deck at a sufficient elevation to allow the unrestricted passage of river traffic so as to make this part of the erection as independent as possible of river conditions. A clearance of 116 feet above low water was decided on. At the adjacent ends of the two fixed spans four wooden cantilever brackets were constructed; these were framed on scows and hoisted into place with the floating sheer leg derrick. Their bases rested on the piers, and their tops were anchored to the fixed spans with four 2½-inch rods for each bracket. On top of these brackets were placed four 120-foot Howe trusses weighing 40 tons each. These were raised into place by using the two skid derricks rigged with 110-foot booms. The iron for this falsework was taken from scrap of old spans removed from the company's line several years ago.

For erecting the towers and sheaves a gallows frame 152 feet high was framed and raised into place on top of the Howe truss falsework. This was anchored back to the truss and hinged at the base so as to allow sufficient rotation to place any member of the towers. The heaviest lift for this frame was a 42-ton tower post section. Steel for these towers was loaded on cars and spotted directly beneath on the railway deck. By leaving out the stringers of two panels of the upper floor system, sufficient clearance was obtained to allow the passage of this material.

The members of the lift span were placed by a two-bent 96-foot high traveler. Steel was delivered to this traveler by a creeper car running on a three-pile tramway supported on the upper deck of the east span and viaduct. Cars were spotted underneath the viaduct and the upper derrick hoisted material from these cars to the creeper car.

Simultaneously with the building of the lift span, its concrete counter-weights were cast in place on falsework. The forms for these counter-weights rested on sand boxes 18 inches deep and were set 18 inches above their proper position. This allowed sufficient play both for stretch of the ropes and ease in connecting the cables. As soon as the lift span was riveted the sand was allowed to run out of these boxes, thus swinging the lift span directly on the counter-weights and allowing the removal of the falsework.

THE NEW RAILWAY BRIDGE ACROSS THE WILLAMETTE RIVER AT PORTLAND, OREGON.

Tides and the Rigidity of the Earth*

Crust-motion Under the Influence of the Sun and Moon

By Prof. A. E. H. Love, F.R.S.

THE publication of a third edition of Sir G. H. Darwin's well-known semi-popular book on the Tides[1] affords an opportunity of forming an estimate of the advances that have been made in recent years in knowledge concerning all those geophysical phenomena which either are directly due to the forces that cause the tides or share with these direct effects some feature rendering them amenable to discussion by similar methods. Sir G. H. Darwin is the greatest living authority on these questions and the fact that nearly one quarter of the third edition of his book is either added or rewritten is sufficient evidence that substantial advance has been made. This advance is not confined to the theory but extends also to the methods of observation and the devising of suitable instruments, besides including a very great increase in the mass of records that are available for the comparison of theoretical results with observed facts. On the purely observational side, perhaps the greatest novelty is to be found in the beginning of actual measurements of the range of the tide in the open sea. On the purely theoretical side, the modifications of Laplace's nebular hypothesis which have been suggested by various writers are specially attractive. But the advances that will prove most interesting to many readers have been made by combining theoretical considerations with observational results in regard to several groups of phenomena from which conclusions have been drawn as to the internal constitution of the Earth. We propose to consider these matters in order.

TIDAL OSCILLATIONS IN THE OCEAN.

By the range of the tide at a place is meant the excess of the depth of water available at high-water for floating a ship at the place above the corresponding depth at low-water. Until recently measurements of the range of the tide were made only at places close to the coasts. They are, in fact, among the results furnished by the use of a tide-gage. It was supposed, chiefly on theoretical grounds, that the range of the tide in the open sea was much smaller. For a complete understanding of the tides, it is desirable to ascertain the range in the open ocean and in partially inclosed seas, such as the English Channel, by direct observation. It appears that ordinary methods of sounding are not available for this purpose and new instruments have been specially devised, one by Capt. Adolf Mensing of the Imperial German Navy, the other by Admirals Mostyn Field and Purey-Cust. The preliminary results obtained by the use of the instrument due to the latter are very striking, a range of tide in the Channel amounting to no less than 24 feet having been measured at a place about midway between Beachy Head and Dieppe. Systematic observations of this kind may be expected to throw much light on the nature of tidal oscillations. The extent to which the tide wave in the Atlantic Ocean, for instance, is an oscillation generated in that ocean by the direct action of the Sun and Moon, as contrasted with a progressive wave, generated in the Pacific and Southern Oceans and entering the Atlantic between the promontories of South Africa and South America, is in some degree a matter of controversy. The systematic study of the tides in the open ocean, as distinct from the ebb and flow along the coasts, may be expected to go far toward settling the question; the whole value of the method of cotidal lines, as developed by Airy and Whewell, depends upon the answer that may be obtained.

Like other natural motions, the tidal oscillations of the ocean, maintained by the attraction of the Sun and Moon, do not take place without friction; and one effect which such friction can bring about is a steady diminution in the speed of the Earth's rotation. The friction of the tides which were in the past raised by the Earth in the Moon, if the Moon once possessed oceans, may in like manner have operated to diminish the speed of the Moon's rotation; this may be the reason why the Moon now always presents the same face to the Earth. Tidal friction in the Earth-Moon system can also cause the Moon to recede from the Earth and it is possible that the Moon was once much nearer to the Earth than it is now, even possible that it was once part of the Earth. The theory of the effects which tidal friction in such a system as that of the Earth and Moon—a moderate-sized planet accompanied by an exceptionally large satellite and revolving around the Sun—were traced in a masterly manner by Sir G. H. Darwin in a series of memoirs published some thirty years ago. The theory was necessarily colored to some extent by the then prevalent scientific ideas concerning cosmogony, ideas derived mainly from Laplace's nebular hypothesis. A perfectly natural chain of reasoning leads directly from the discussion of the theory of the tides, through tidal friction, to the most speculative regions of thought as to the origin and evolution of planetary and stellar systems.

EVOLUTION OF PLANETARY SYSTEMS.

Until recently Laplace's hypothesis held the field; though the authors of some modern theories might demur to such a description, it still seems fair to describe all the more recent hypotheses as modifications of that propounded by Laplace. Darwin himself broke away somewhat from the Laplacian doctrine when he suggested that the Moon became detached from the Earth as a single satellite and not as a ring. J. H. Jeans broke away still more when he suggested that gravitational instability or the tendency of gravitating matter to concentrate about local nuclei, rather than increased speed of rotation due to cooling, might have been the cause of the disintegration of the primitive nebula into detached masses. But the modern revival of interest in the nebular hypothesis is largely due to the criticisms levelled against it by T. C. Chamberlin and F. R. Moulton and the propounding by them of a view put forward as alternative and named the "planetesimal" hypothesis. In this view the solar system is supposed to have been developed from a spiral nebula, a type of celestial object with which modern telescopes have made us familiar, consisting of a central condensation from opposite parts of which there emanate a pair of spiral arms. Such an object is supposed to have originated from a single star through enormous tidal forces set up in it by passing near to another star. The assumed partial disintegration thus effected in the parent star and the mode in which subsequently aggregation of the ejected matter into planets and satellites might have taken place offer problems so intricate as to defy calculation; the indications that can be obtained certainly seem to suggest that we have in this theory a modification of Laplace's free from many of the difficulties inherent in his original form.

EARTH-TIDES.

The body of the Earth, on which the oceans rest, cannot be absolutely rigid. No body is. It must be deformed more or less by the attractions of the Sun and Moon. If we can find out in what manner it is deformed and how much, we can draw inferences in regard to its internal constitution. Thus there arises the problem of *earth-tides:* How can such tides be observed? What conclusions in regard to the state of the matter within the Earth can be drawn from the observations? The movement eludes direct observation. A tide-gage can record the rise of water above a marked level near a coast and other instruments can do the same thing for the rise above a level measured from the sea-bottom out at sea but the would-be observer of earth-tides has no mark from which to measure. His methods of observation must perforce be indirect. The first attempts were directed to finding the actual height of the so-called fortnightly tide. By the fortnightly tide is meant a minute inequality in the tide-height, having a period of about a fortnight, depending upon the inclination of the Moon's orbit to the plane of the equator. The point at which the Moon is overhead is not always or generally a point on the equator but travels round and round the Earth in a sort of spiral path. The whole spiral lies between two extreme turns, one of the most northerly, the other the most southerly, which, however, are not fixed but vary in position from time to time. If we follow the movement of the point, beginning at an instant when it has an extreme northerly position, we find each successive turn of the spiral lying to the south of the preceding turn, until at the end of a fortnight an extreme southerly position is reached. After this the path turns to the north and during the next fortnight each successive turn of the spiral lies to the north of the preceding turn. This movement of the Moon causes an inequality in the tide-raising force with a period of a fortnight and this inequality in the force affects the observable height of the tide with an inequality of the same period. It is as if, in addition to the tide that comes in twice a day, there were a tiny tide that comes in twice a month. The method of harmonic analysis of tidal observations can draw out from a long series of observations the amount of this tiny tide, just as a suitably tuned resonator can pick out one of the component tones of a musical instrument or of an orchestra. Now the amount which the fortnightly oceanic tide would have if the Earth were absolutely rigid can be calculated. The result that it may be calculated by the so-called "equilibrium theory" was first asserted on insufficient grounds, then denied on the basis of a more rigorous investigation and finally proved by taking account of a circumstance neglected in that investigation. The adventures of this result form a curious chapter in the history of science but must be omitted here. It is now well established. The comparison of the observed and calculated values is one of the methods available for determining the height of earth-tides. Clearly, if the observed value be nearly equal to the calculated, the Earth yields but little; if the observed value be much less than the calculated, the Earth yields a good deal. In the former case it is very stiff or of great rigidity, in the latter the rigidity is small. If the Earth were fluid inside there should be very little fortnightly tide. As a matter of fact, the observed value is nearly two thirds of the calculated. This result forms an essential part of the famous argument invoked by Lord Kelvin to prove that the Earth cannot consist of a molten fiery core covered over with a thin solid crust.

This argument is greatly strengthened when it is found to be confirmed by others derived from a study of other phenomena than the fortnightly tide. The attraction of the Moon tends to draw a pendulum to one side. The force available for this purpose is not the full amount of the Moon's attraction but the difference between the amounts of this attraction at the center of the Earth and at the place where the pendulum is hung; and of this difference the horizontal component only can affect the direction in which the pendulum hangs or the apparent vertical. The maximum amount of the available force being only about one eleven millionth of gravity, it is necessary to magnify the effect. This is done by using a horizontal pendulum, that is to say, a pendulum free to swing about a nearly vertical axis. The deflexion of the pendulum measures the force acting upon it. If the Earth were absolutely rigid, the Moon would act upon the pendulum with a certain force, as above. It is necessary to take numerous precautions to shield the pendulum from disturbances, such as those due to draughts, to the heating of the soil by the Sun during the day and its cooling at night, even to the tilting of the floor by the weight of the observer. All these difficulties were overcome by Dr. O. Hecker, who installed two horizontal pendulums in an underground chamber at Potsdam and recorded their movements during several years. On analyzing his results, he showed that the actual movement of the pendulum is about two thirds of what it would be if the Earth were absolutely rigid. Hecker's measurement of the lunar deflexion of gravity is a very remarkable achievement. It recalls and evidently confirms the result obtained by analyzing tidal observations to pick out the fortnightly tide; and it has itself been confirmed by another series of experiments with horizontal pendulums carried out by Dr. A. Orloff at Dorpat. It is important to note that the deflexion of the pendulum or at least that part of it which is periodic in half a lunar day keeps time with the Moon.

The proper interpretation of these results is a matter of some difficulty. The registering by the horizontal pendulum of a deflexion less than that due to the Moon's force is evidence that it is under the action of other forces which keep time with the Moon; and it is an immediate inference that these forces are due to the deformation of the Earth by the Moon's tide-raising force. This force alters very slightly the shape of the Earth, elongating it toward the Moon and in the opposite direction and flattening it all round at the places where the Moon is near the horizon. The change of shape produces in the supports of instruments a slight tilt and consequently a horizontal pendulum is subjected to a small force which may be described as the "force due to tilting." It is easy to see that the force due to tilting acts against the Moon's tide-raising force. But this is not the only extra force which is exerted on the pendulum. The elongation of the Earth in one direction, combined with the flattening in all perpendicular directions, causes a change in the attraction of the Earth or a genuine alteration of gravity, due to the attractions of the tidal protuberances and the loss of attraction that accompanies the tidal flattening. This additional force, the genuine alteration of gravity, may be described as the "change of attraction." It is easy to see that it acts so as to reinforce the Moon's force. The observed result is interpreted in the statement that the force due to tilting exceeds the change of attraction by an amount equal to about one third of the Moon's force. Now if we knew the force due to tilting, we should know how much the surface is tilted and thence how much the Earth yields to the tide-raising forces. If we knew the change of attraction, we could then use the result obtained by observing the deflexion of the horizontal pendulum to infer the force due to tilting and thence, as

* Reproduced from *Science Progress.*

[1] "The Tides and Kindred Phenomena in the Solar System," by Sir George Howard Darwin. Third edition. London: John Murray, 1911.

before, find the amount by which the Earth yields. But the pendulum result will not tell us how much the Earth yields, because all it can possibly give is the difference between two forces; what we want to know is the magnitude of one of them. Observations of the fortnightly tide cannot give us any additional information. They can only tell us what the horizontal pendulum tells us.

The ambiguity of the interpretation to be put upon the results obtained from observations of the fortnightly tide and of the behavior of horizontal pendulums should make us cautious about accepting statements as to the rigidity of the Earth, when such statements are founded upon observations of these kinds only. It is true that Lord Kelvin proved long ago that, if the Earth were homogeneous and incompressible, it would have to be as rigid as steel to make the observable height of the fortnightly tide as much as two thirds of that calculated by the equilibrium theory. The fact that the observed height is of about this amount does not enable us to infer that the actual Earth, which is neither homogeneous nor incompressible, is as rigid as a ball of steel. To obtain sufficient evidence for a judgment on this matter it is necessary to have recourse to a different kind of observations and the observations that have proved effective have to do with a phenomenon that has no obvious relation to tides or the lunar deflexion of gravity—the phenomenon of variation of latitude. It has been known for a long time that the latitudes of places on the Earth's surface are not quite fixed or, what comes to the same thing, that the North and South poles are not quite fixed points on the Earth's surface. It has become known more recently that the Poles move in irregular paths about mean positions, round which they circulate in a period of about fourteen months. The period which this movement would have if the Earth were an absolutely rigid body is well known to be about ten months; one reason why the actual periodic movement, with a fourteen-months' period, remained so long undiscovered was that observers sought in their records for traces of a ten-months' period. The lengthening of the period from ten months to fourteen is due to the yielding of the Earth. A movement of the Poles means a change of the instantaneous axis of rotation; this is necessarily accompanied by a change in the so-called "centrifugal force." The adjustment of the Earth to rotation about one axis after another involves a deformation, in exactly the same way as if it were subjected to forces which are the differences between the centrifugal force referred to, the actual axis and the centrifugal force referred to an axis passing through the mean positions of the poles. Exactly as in the case of tidal forces, the deformation implies a tilting of the surface and a "change of attraction." The lengthening of the period has been proved to depend upon the change of attraction not upon the tilting of the surface; and the law according to which the change of attraction is connected with the force causing deformation, in the case of variation of latitude the inequality of centrifugal force, has been made out. Further, it has been proved that the law connecting the change of attraction with the force causing deformation must be exactly the same, whether the force in question be an inequality in centrifugal force or a tide-raising force. The result is that from the period of variation of latitude we can infer the change of attraction due to the tide-raising forces.

To determine the actual height of earth-tides it only remains to combine the results of observation in regard to variation of latitude with those of horizontal pendulum experiments. The change of attraction, the force due to tilting, the amount of the deformation have all been determined. But from this information we cannot infer much more about the rigidity of the Earth than that on the whole it is great. It is impossible to fit all the observations by treating the Earth as a body of one definite rigidity throughout. Being heterogeneous as regards density it may be expected to be so in regard to rigidity as well. It is perhaps not very surprising that it should be possible to fit all the observations by the assumption of a core of greater density inclosed in a crust of smaller density, provided the core be stiffer than the crust; and it is interesting to note that, if the crust be taken to be about 1,000 miles thick and to have the average density of surface rocks, while the core is taken to have the density of iron, the average rigidity of the core, computed on the hypothesis of incompressibility, must be nearly three times that of steel, while the average rigidity of the crust, computed on the same hypothesis, may be much less than that of steel and indeed less than that of most hard rocks.

RIGIDITY OF THE EARTH.

The inference that the greater part of the body of the Earth must be solid and very rigid has been confirmed in a remarkable way by the results of seismological investigations; indeed, the perhaps unexpected conclusion that the inner parts must be more rigid than the outer appears to be required as part of the interpretation of seismic records. The systematic recording by suitable instruments of seismic disturbances transmitted to great distances has been practised for a relatively short time but the results that have been obtained by means of such records have already proved to be of the highest value for geophysics. When a great earthquake takes place it affects seismographs all over the world; the records always conform to one type, a series of minute tremors being followed by a series of much larger oscillations which subside gradually. When the distinction between the preliminary tremors and the large waves was first noticed, it was supposed by some writers that they were to be classed respectively as longitudinal and transverse waves, in accordance with the well-known physical principle that waves transmitted through an elastic solid body are of two types—waves of compression or rarefaction, characterized by movement parallel to the direction of propagation; and waves of distortion, unaccompanied by change of volume, characterized by movement transverse to the direction of propagation. As the records accumulated and the theory of elasticity was improved, it was seen that this simple classification could not be maintained. On the one hand it was found that the preliminary tremors arrived at distant places at such times as to indicate direct transmission through the body of the Earth with a nearly constant velocity, while the larger waves appeared to be transmitted over the surface of the Earth with a smaller nearly constant velocity. Further, it was found that both the preliminary tremors and the large waves were composite. After the tremors have been going on during a few minutes, a second series of tremors, showing certain characteristic differences from the first, begin to be received, and the result has been established that the movement is mainly longitudinal in the first series, mainly transverse in the second. Both series appear to travel through the body of the Earth with nearly constant velocities. Again it has been found that the large waves present a number of distinct phases, the most important being an initial phase, in which the movement of the ground is mainly horizontal and transverse to the direction of propagation; and a maximum phase, in which the horizontal movement of the ground is mainly parallel to the direction of propagation and is accompanied by considerable vertical movement and a phase of subsidence.

Concurrently with the accumulation of seismic records and the classification of the types of movement which they disclose, there has been a considerable development of the physicomathematical theory by means of which an account of such movements can be rendered. The first step was the discovery by Lord Rayleigh of a third type of waves. A disturbance set up in a solid body spreads out in a composite wave, which gradually resolves itself into two waves, one of compression, the other of distortion, with a peculiar type of motion between the two. When the front of a wave reaches a bounding surface reflexion takes place; the reflected waves are in general composite at first and resolve themselves gradually into pairs of waves of the two special types. The effect of a bounding surface is therefore to produce changes which may disguise the simplicity of the resolution into the two types; the result which Lord Rayleigh found was that disturbances emerging at the surface give rise to a distinct class of waves, which travel over the surface with a nearly constant velocity and never affect appreciably the matter at any considerable depth beneath the surface. Waves of this type are characterized by a horizontal movement parallel to the direction of propagation, accompanied by considerable vertical movement. The conclusion that the maximum phase of seismic movement must be transmitted by waves of this type seems inevitable. The phase of subsidence might be supposed to be due to the frittering away of the energy through internal friction; doubtless this cause plays a part but it has been proved by Prof. H. Lamb that waves which spread over a surface, as distinguished from waves which travel through a body, are always prolonged in a kind of "tail," showing a gradual diminution of intensity, quite independently of any dissipation of the energy. The characteristic feature of the initial phase of the large waves, viz., the transversality of the horizontal displacement, can be explained only by taking account of the heterogeneity of the Earth's substance. Waves possessing this feature can travel through a superficial layer, provided the rigidity of the subjacent material be greater than that of the layer.

By regarding the Earth as made up of a nucleus and a moderately thick superficial layer or crust and attributing suitable mechanical properties to the nucleus and to the crust, we can arrive at a fairly consistent representation of the various phenomena. The first and second phases of the preliminary tremors are, in this representation, taken to be due respectively to compressional and distortional waves which travel through the body of the Earth and emerge at the surface. The initial phase of the large waves is taken to indicate the passage of waves of transverse horizontal displacement transmitted through the crust; the maximum phase to indicate the passage over the surface of waves of Lord Rayleigh's type; and the phase of subsidence to be the expression of the tails in which both these types of waves would necessarily be prolonged. The values to be attributed to the physical quantities by which the state of the parts is specified are not completely determinate, a change in the assumed density, for instance, being accompanied by a change in the inferred rigidity. But the indeterminateness is confined within relatively narrow limits. The order of magnitude of the rigidity required in the nucleus or at least in its more central portion is about three times the rigidity of steel. This value may seem very large; but, when we reflect upon the enormous pressures which must be developed within the Earth by the mutual gravitation of its parts, it becomes less surprising. A similar value was inferred by combining the result of horizontal pendulum experiments with the result of observations concerning variation of latitude. The value required in the crust is about the average rigidity of many kinds of granite and marble. The result that, for the proper transmission of the initial phase of the large waves, the rigidity should increase beneath the crust, points to a gradual transition from the mechanical properties of the crust to those of the nucleus, a thing probable enough. The general result that the Earth as a whole is a very rigid body, not a fluid body coated over with a thin solid crust, is so well supported by the observations of the fortnightly tide, by the experiments with horizontal pendulums, by the period of the variation of latitude and by the interpretation of seismic records, it is regarded as firmly established.

Scientific Methods in Earthenware Manufacture

It has been said that the technology of the lower grades of pottery (common earthenware, Rockingham ware, majolica, faience, and stoneware) is comparatively simple; this is undoubtedly correct, viewing the earthenware industry as it exists to-day, but it is also true that less advantage has been taken of scientific methods and research in earthenware manufacture than in other industries. Harkort has recently discussed (*Zeit. angew. Chem.*, xxiv., 2,348) the composition of earthenware bodies and its relation to scientific results; it is from this contribution that the following material is taken.

The strength of earthenware is dependent, not as in porcelain on the fusion of felspar, but principally upon the close packing of the clay particles; it follows, therefore, that a determination of strength merely by the "ring" of the articles leaves out of account such factors as thickness, shape, etc. The value of earthenware depends, to a large extent, upon the flawless adhesion of the glaze, and as a defect may not become apparent for a considerable period, a rapid method of testing is important. Harkort heats the test-pieces in an electric oven, in which the temperature is gradually increased, and quenches them in water from different temperatures. His observations, extending for a year, have demonstrated that test-pieces which will stand higher temperatures withstand ordinary variations of temperatures longer; and that if no cracks are developed at a certain quenching temperature, a satisfactory deportment toward changes of temperature can be predicted. Seger attributed the formation of cracks and the splitting off of a glaze to a difference between the coefficients of expansion of the body and the glaze. Damaur made measurements on earthenware bodies and confirmed Seger's assumption; he showed that the coefficient of expansion increased with an increase in the silica content, but was affected by the temperature of firing, if this is raised to the point of fusion. Harkort finds that silica lowers the expansion in glazes, but in sintered bodies the opposite effect is observed, since it retards the drawing together of the particles of clay substance; and that when the silica is fine-grained, the bodies are less liable to have glaze cracks. By means of his quenching process, definite limits have been found for the ratio of clay substance to silica in earthenware bodies. A certain amount of clay substance must be present to yield an easily workable body, but the silica content must be such that the coefficient of expansion represents an applicable value. It is pointed out that while finely ground silica must be added as sand is eliminated from well washed clays, its addition has a tendency to weaken a body, and a high temperature of firing which would tend to strengthen would be disadvantageous from the point of view of the formation of glazed cracks, as the density developed promotes their formation. It is found that the larger the fire-shrinkage is, the smaller the coefficient of expansion, and the greater the sintering the larger the expansion. Additions of lime and felspar increase the strength of the biscuit; the effect of the felspar is attributable to its fusion, but at that temperature deformation results, although this is not observed when lime is added in amounts up to 20 per cent; lime alone softens a body, and the burning temperature is slightly increased.—*Journal of Industrial and Engineering Chemistry.*

Lunacy Statistics.—Fifty years ago we had one lunatic in 575 of the population, now one in 236. At this rate, in 300 years there will be more insane than sane people in the world.

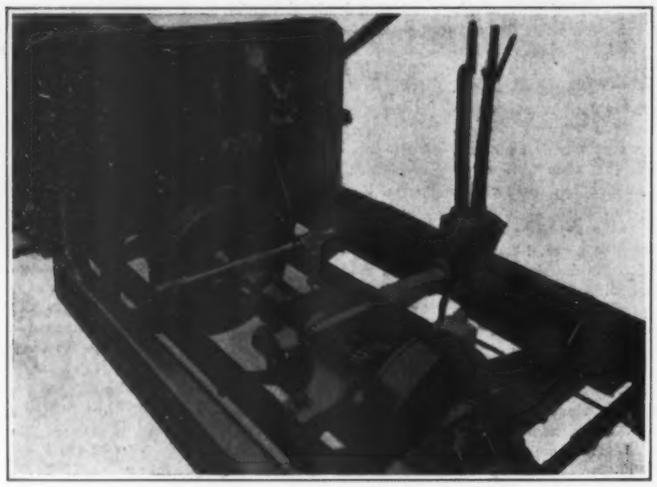


Fig. A.—Part of Chassis Showing Gear Box.

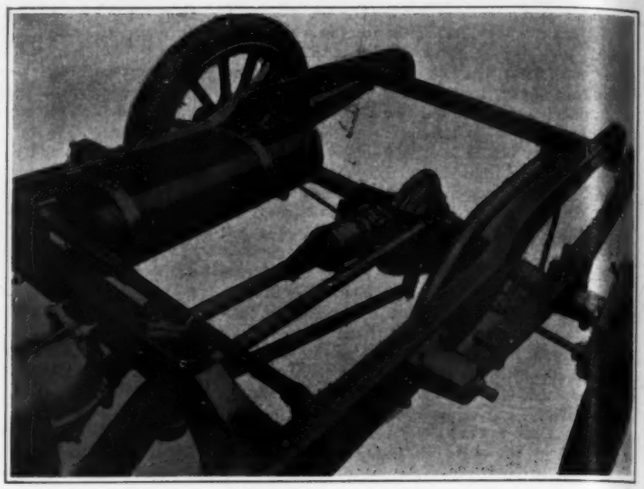


Fig. B.—Part of Chassis Showing Back Axle.

An English Self-starting Motor Car

Sixteen Horse-Power Four-cylinder Automobile With Compressed Air Self-starting Device

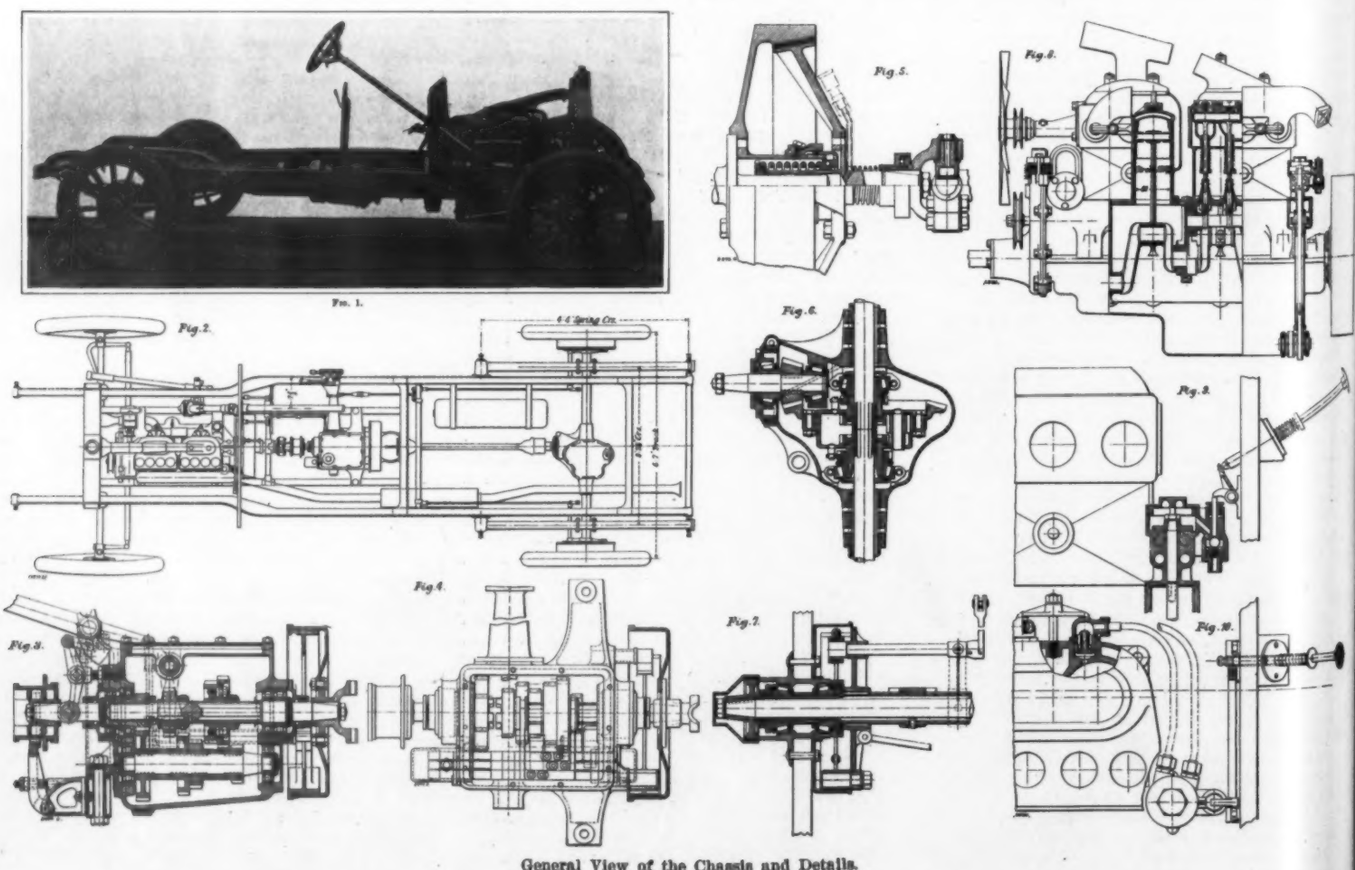
THE following description, reproduced from *Engineering*, of an English motor car of the most modern type fitted with self-starting mechanism, will be of interest to many of our readers. The car differs radically from many others upon the English market in having this feature of a compressed air self-starter.

To the best of our knowledge the firm was the first to adopt this form of self-starter in England, and, in view of its convenience and success, it is not surprising to find that they have embodied it as a permanent feature of their practice.

In describing the car it will be convenient to deal, in the first instance, with the frame, and from that to pass to the gearing, transmission and axles, concluding with an account of the engine. We accordingly direct attention, in the first instance, to Figs. 1 and 2, which show a photographic side view of the car and a detail plan. It will be seen that the frame is of the usual channel section, and that it is strengthened at the in-sweep between the body and the engine by widening the flanges. The frame is up-swept at the rear end in order to permit the use of low side-entrance doors. The gear-box and engine are supported on special fore-and-aft runners, which are carried by the cross-members of the frame. The engine we will refer to later, but we may here, in connection with Fig. 2, trace through the drive from the engine to the back axle. Immediately behind the engine there is the usual clutch, which is of the cone type, and between it and the gear-box is a double universal joint, which can be seen in Fig. 2. Behind the gear-box there is a foot-brake of the drum type, with internal expanding shoes, and behind this again the main universal joint coupling to the Cardan shaft. At the back end of the Cardan shaft there is a further universal joint which connects up with the differential gear. The general arrangement of the back axle will be clear from Fig. 2, but we will refer to it in detail in connection with some of the later figures.

The gear-box is illustrated in Figs. 3 and 4, but before dealing with it attention should be directed to the clutch, which is shown in Fig. 5. This figure clearly shows the construction, while the operating pedal mechanism can be seen in Figs. 2 and A. The pedal top, as can best be seen in Fig. 2, is arranged to be adjustable for tall or short drivers. Fig. 5, in conjunction with Fig. 3, shows the double universal joint which lies between the engine and gear-box. It will be clear that the provision of this double joint must eliminate any wear which might take place owing to the engine and gear-box being slightly out of line. The lubrication of the clutch and double universal joints is arranged for by self-contained grease-cups.

The gear-box is of the sliding type, with four speeds and a direct drive on top speed. It is shown in cross-section in Fig. 3. Before referring further to the gear-box, as shown in this figure, however, it should be pointed out that the clutch operating mechanism, as shown at the left-hand side of this figure, is now obsolete, and that a different arrangement is fitted to the car we are describing. The new arrangement is not well shown



General View of the Chassis and Details.

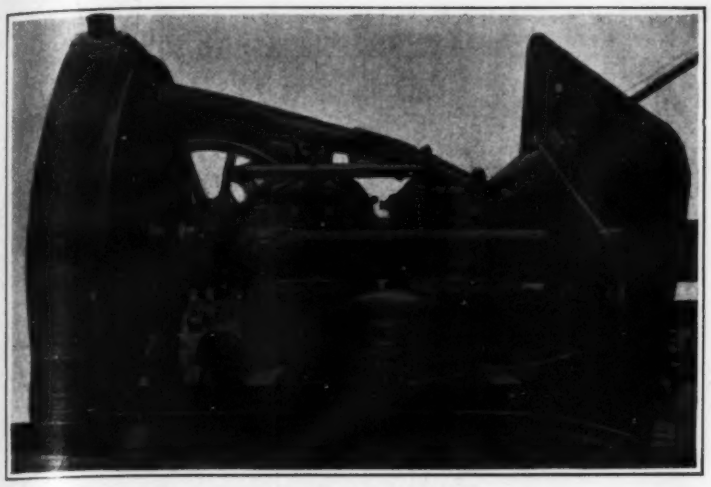


Fig. C.—View of Engine from Near Side of Car.

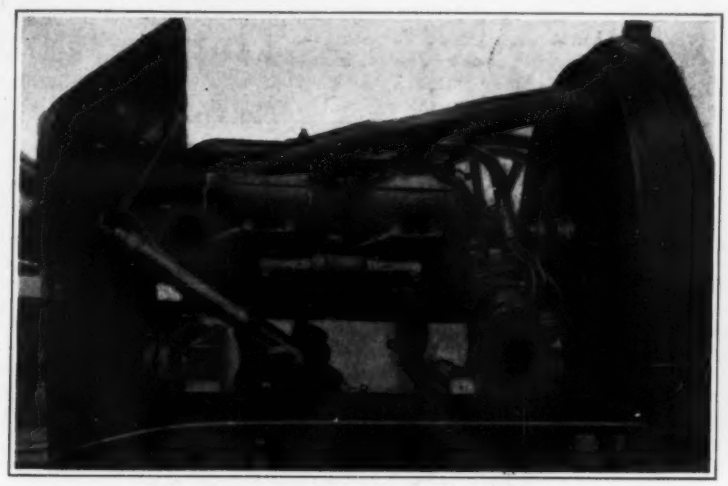


Fig. D.—View of Engine from Off-side of Car.

in any of the drawings we reproduce, but it may be said that it consists of a simple finger, which is attached to the cross-shaft carrying the pedal, and which acts direct on the ball-bearing collar shown at the righthand side of Fig. 5. We specially mention this detail as it is illustrative of the great attention which has been paid to the simplification of this car, and the skill with which any unnecessary pins and joints have been eliminated. It is only by a process of evolution that such a complex mechanism as a motor car can reach its ideal simplicity, and this clutch-operating gear illustrates one of the further advances which this design makes as compared with earlier models.

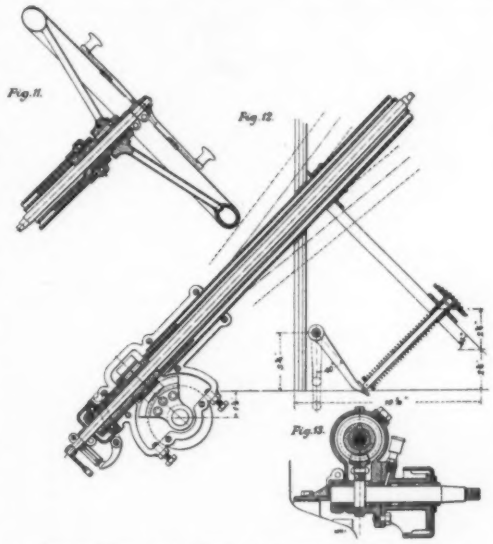
Little need be said in detail about the gear-box, as it is well shown in the cross-section and plan in Figs. 3 and 4. It is of the four-speed sliding type, and gives a direct drive on top speed. The various speeds are controlled by a side lever working in a gate, as can be seen in Figs. 2 and A. In addition to the gear-box, Figs. 3 and 4 show the Cardan shaft brake, which is of the metal-to-metal internal expanding type. The shoes, which are adjustable for wear, are operated by a foot-pedal through a lever and link mechanism, which can be partly seen in Figs. 2 and A. Details of the main universal joint coupling the gear to the Cardan shaft are not shown in any of our illustrations, but it should be said that this joint is completely inclosed in an aluminium case, which is stationary, and which contains oil, into which the joint dips. This oil-case, which is well shown in Fig. B, can be refilled from outside without it being necessary to take up any floor-boards.

The differential gear and the center part of the back axle are shown in Fig. 6, while one end of the back axle is shown in Fig. 7. The axle can also be seen in the view of the rear end of the chassis given in Fig. B. The differential gear casing is arranged with a door big enough to permit of the withdrawal of the differential gear and bevel, if necessary, although the axle is not split across the center. The axle can be dismantled without removing the wheels or jacking up the car. It will be seen from Fig. 6 that conical roller bearings are fitted to the differential. These bearings are of the Timkin type. It will also be seen, from Fig. 7, that similar bearings are fitted to the rear wheels. The use of these bearings allows the rear wheels to be adjusted for wear by the screwing-up of a single nut. Fig. 7 clearly shows the method of taking the weight of the car on the axle-sleeves, the drive only being taken by the axle-shafts. The figure also shows one of the internal expanding rear brakes. These brakes are operated from a side lever through the coupling arrangement shown in Figs 2 and A. Semi-elliptical springs are used for both the rear and front axles, those for the rear axle being 52 inches long from eye to eye. The lubrication of the rear axle is looked after by self-contained oil-baths.

The arrangement of the front axle and the steering gear will be seen in Figs.1 and 2, and in Figs. 11 to 13, below. The axle is a drop-forging of I-section, and the wheels run in conical roller-bearings. The steering gear is of the irreversible worm and segment type, as can be seen from Figs. 12 and 13. All steering joints are fitted with grease-cups, which are made of such size that there is little likelihood of any of them being overlooked when the car is being greased up. All joints are fitted with leather covers to keep out dust. The steering column and its parts are neatly worked out, as will be seen from Figs. 11 to 13, which clearly show the details of the spark advance and throttle control. The foot-pedal which is shown in Fig. 12 is for the rapid control of the throttle, and acts as an alternative to the hand-lever.

The engine is shown in cross-section in Fig. 8, while Figs. 9 and 10 show details of the self-starting gear. Views of the right and left-hand sides of the engine, fitted in place in the chassis, are given in Figs. C and D. No great reference need be made to Fig. 8, as the various details of the engine are there well shown, and except in the self-starting gear, which we will refer to in a moment, the engine differs but little from that fitted on cars of the preceding year.

Attention should, however, be drawn to the accessibility of the various parts, particularly the magneto and carburetter, which, as can be seen from Figs. C and D, are so placed that they may be attended to, or adjusted, at any time with ease and without dismantling anything. The engine is of Désaxé construction, and has four cylinders 88 millimeters bore by 120 millimeters stroke, cast in pairs. Thermo-syphon cooling is adopted, while the radiator is of the gilled-tube type, and is assisted by a fan, as shown in Figs. C and D. Lubrication is by forced feed from a displacement pump, which can be seen in Fig. 8, and which is driven by the same vertical spindle which



Arrangement of Front Axle and Steering Gear.

drives the distributing-valve of the self-starter arrangement. (We refer to this distributing-valve in the next paragraph.) The pump draws, through a filter, from a sump in the bottom of the crank-chamber, and delivers to the main bearings and also to the gear-wheels which drive the magneto, etc. It also delivers to shallow troughs placed below the big ends of the connecting-rods, and into which scoops carried by the big ends dip. There is a mechanical indicator, carried on the dashboard from which the driver can tell when the pump is working.

The self-starting gear consists of a small single-cylinder air-compressor, which is situated at the front end of the engine, and can be seen in Figs. 8 and D. This compressor delivers air to a cylindrical receiver, which is carried at the rear part of the chassis, as shown in Figs. 2 and B. The maximum pressure is about 300 pounds per square inch, the compressor running idle after this pressure is reached. The supply of the air to the various engine-cylinders for starting up is controlled by a distributing-valve, which is shown in section in Fig. 9, and plan in Fig. 10. When it is desired to start the engine air is admitted to the top side of this distributing-valve by means of the pedal-operated ball-stop valve shown. The distributing-valve consists merely of a circular plate, which rotates continually, and in so doing makes connection, by means of a port carried through it, between the air-supply side and four lower parts which are connected up to pipes running to the four cylinders of the engine. These pipes can be seen in Figs. 10 and C. The pipes terminate in spring-controlled valves, which admit the compressed air to the cylinders, but which, when the air supply is cut off and the engine is running normally, are held closed by their springs, and the internal pressure. The arrangement will be quite clear from Fig. 10. When starting up air is supplied to the cylinders for a few revolutions until explosion starts, when the air is cut off and the engine runs on gasoline.

In addition to its service in starting the engine, the compressed-air system is also employed, when required, for inflating the tires or lifting the car by means of a jack, when it is desired to remove a tire or carry out other work. For these purposes a valve and connection are fitted to the dashboard, up to which a rubber-tube connection is made. We can from personal experience speak of the extreme convenience of having the air-pressure available for these extra services, the saving in time and trouble which results being very considerable. The convenience of the air system from the starting point of view is obvious, but it should, perhaps, be pointed out that its use is likely to result in a considerable saving in gasoline, as there will never be any hesitation in cutting off the fuel supply for short standing periods, as there will may be when such an action involves dismounting from the car to re-start again. In conclusion, we should say that the engine has an R. A. C. rating of 19.2 horse-power, and that the makers guarantee it to develop 30 brake horse-power at 2,000 revolutions per minute.

Number of Species of Living Vertebrates

WRITING in *Science*, H. W. Henshaw says: "Recently I have had occasion to make an estimate of the number of known species of living vertebrates. After consultation with a number of specialists, the figures below have been fixed on as a reasonably close approximation to the truth. Thinking these estimates may be of interest to others, I publish them for what they are worth. Such figures cannot, of course, be accurate if for no other reasons than that in compiling them no attempt has been made to discriminate between forms described as species or as subspecies or varieties, or to determine how many of the named and recorded species will ultimately have to be relegated to the scrap heap and be listed only as synonyms. Still less is the rôle of prophet assumed and an attempt made to go beyond present returns and indicate how many vertebrate species yet remain to be described, although it is believed that in the case of some orders (as, for instance, birds and mammals) reasonably good guesses might be made. The estimate is as follows:

1. Mammals	7,000
2. Birds	20,000
3. Crocodiles and turtles	300
4. Lizards	3,300
5. Snakes	2,400
6. Frogs and toads	2,000
7. Salamanders	200
8. Fishes	12,000
Total	47,200

Color and Constitution of Water

ACCORDING to an investigation carried out by J. Duclaux and E. Wollman, the color of 6 meters of water at 0 deg. Cent. is equal to that of 2 centimeters of a 4 per cent solution of $CuSO_4 . 5H_2O$. At 35 degrees the color is more green, and is equal to that of 2 centimeters of 1.60 per cent $CuSO_4 . 5H_2O$ plus 2 centimeters of 0.025 per cent $K_2Cr_2O_7$. A similar change of color is produced by the addition of colorless salts, which demand a diminution in the quantity of copper sulphate and an addition of dichromate in the comparison cells, to restore the balance previously existing. Both changes can be explained as due to the conversion of blue dissolved "ice-molecules" into "water-molecules" differing perceptibly in tint.

The Fertility of the Soil*

Recent Advances in Agricultural Science

By A. D. Hall, F.R.S.

FROM an ordinary common-sense point of view the fertility of the soil is best defined as that property for which a man pays rent—the property which causes some land to let for £2 or £3 an acre, whereas the adjoining land may be dear enough at 10s. With the causes of this fertility I do not propose to deal at any great length this evening more than to indicate that it is the outcome of a very complex series of factors, among which we can enumerate the actual supply of plant food in the soil, its mechanical texture as conditioning the movements of water, and the particular micro-fauna and flora inhabiting the soil, for upon these lower organisms depends the facility with which the material contained in the soil will become available for the nutrition of the plant. For the purpose of the present argument it will be sufficient to fix our attention upon the amount of nitrogen in the soil as the main factor determining fertility, because, in the first place, nitrogen is one of the necessary and most expensive elements in the nutrition of the plant, and, secondly, because its amount in the soil is subject to both gains and losses from causes which are more or less under the control of the farmer. The other essential elements which the plant has to draw from the soil—for example, phosphoric acid and potash—are only subject to slight losses by solution in the drainage water, and cannot be added to except deliberately by the action of the farmer; but in the case of nitrogen we have, in addition to the small stock of combined nitrogen in the soil, the vast store of free gaseous nitrogen with which both soil and plant are in contact. We may take it as settled nowadays that the plant itself can make no use of nitrogen gas, but must draw combined nitrogen in one of its simpler forms, such as nitrates or ammonia, from the soil. Among the bacteria of the soil, however, there are two great groups, one of which is capable of breaking up compounds of nitrogen and setting free the element as gas, whereas the other can take free gaseous nitrogen from the atmosphere and bring it into a combined form. Which of these two groups will be more active depends upon the conditions prevailing in the soil, and goes far to determine both its current fertility and the length of time during which it will be capable of bearing crops.

The question of the duration of the fertility of the land under continual cropping has excited much attention of late, chiefly because the United States has begun to take alarm about the reduced production of some of its most fertile lands, as, for instance, the old prairie lands of the middle west—a reduced production which, among other causes, has helped to set in motion a stream of migrants from the United States to the newer lands of the Canadian northwest. In the development of agriculture three distinct stages may be observed. In the first place, we may have a process of pure exploitation of the initial resources of the soil, when the farmer is to all intents and purposes mining in its fertility. This is the process which, in the main, has been going on in America, and, indeed, in all the newer countries which have been opened up to agriculture during the last two centuries. Not all virgin soils are rich, and the system of cropping alternately with wheat or maize which prevails over so much of North America has reduced great areas of the land in the eastern States to such a poverty-stricken condition that it has been allowed to go derelict. In the great plains, however, where the first settler found four or five feet of black soil, containing nearly half per cent of nitrogen, the land has kept up its productivity almost unimpaired for nearly a century. If we suppose the black soil only extended to a depth of three feet, and contained three tenths per cent of nitrogen, both limited estimates, there would still be 30,000 pounds of nitrogen per acre—that is to say, nitrogen enough for five hundred crops larger than the American farmer has been accustomed to win from that land—and yet in less than a century such soils are beginning to show signs of exhaustion. The farming of the kind just described is destructive; but in the older lands of the west of Europe, which have been under cultivation for something like a century, a conservative system has been devised which is capable of keeping up the productive power of the soil, though not, perhaps, to a very high pitch. Perhaps the best example of this may be seen in the Norfolk four-course rotation prior to the introduction of artificial fertilizers. In this system a turnip crop, which was either consumed on the ground or converted into manure, and so returned to the soil, was followed by barley in which clover was sown, and the clover, which also got back to the soil, was followed by wheat. The farming covenants prevented the sale of anything more than barley and wheat grain, and the meat that was produced by the consumption of the turnips and hay. Thus but a small proportion of the nitrogen taken out of the soil by the crop left the farm; the rest was returned and used over again, although considerable losses of gaseous nitrogen occurred during the making of the dung. Both losses, however, were more than replaced by the nitrogen which the clover crop gathered from the atmosphere during its growth. At any rate, we find that under such a conservative system of farming the productivity of the land remained pretty constant at about a level of twenty bushels to the acre from the time of Queen Elizabeth down to the beginning of the nineteenth century. This conservative farming about 1840 began to give place to the third stage in the development—intensive farming, rendered possible by the discovery of artificial fertilizers and the cheap freights which brought foreign fertility in the shape of cheap feeding stuffs to the soil of this country. By these means the average production of the land of the British Isles has been raised from the twenty-bushel level to something over thirty bushels, and the most intensive farmers reach an average level at least 25 per cent higher. In their case the soil has become practically a manufacturing medium transforming the nitrogen and other fertilizing materials added to it into crops, giving nothing to those crops from its original stock, and indeed up to a certain point gaining rather than losing fertility with each year's cultivation. The inner history of these three stages in agriculture may be followed by a consideration of certain experimental plots at Rothamsted. We may begin with the experimental wheatfield which is now carrying its sixty-ninth successive crop of wheat. One of the plots has been without manure throughout the whole of that period. The production, which fell steadily for the first ten years, has since that time remained so constant that the slow falling off which we still believe to be taking place is disguised by the fluctuations due to season. The average yield is about twelve bushels to the acre, almost exactly the average yield of the wheat lands of the whole world. Unfortunately samples of soil were not taken at the very outset, but if we begin with the earliest analyses that were available in 1865 and draw up a balance-sheet for the nitrogen, we shall find that the removal in the crop is almost exactly balanced by the small amount that comes down in the rain and the decrease that has taken place in the amount of nitrogen in the soil. There are, however, other losses of nitrogen not brought into account; some is washed away by drainage water every year, and a further small unestimated amount gets removed as weeds. As these losses do not appear in the balance-sheet we must conclude that some recuperative action is at work keeping up the stock, though the process is not sufficient wholly to make up for the removals in the crop. The results of this plot show two principles at work—the tendency of the land under an unchanging system of farming to reach a position of equilibrium when the only variations in the crop are those brought about by seasons; and, secondly, that regeneration of the nitrogen stock in the soil is possible by natural causes alone.

EXPERIMENTS ON WHEAT, BROADBALK FIELD, ROTHAMSTED.

Average Produce of Grain, first 8 years (1844-51) and the successive 10-year periods 1852-1911.

Plot	Manure	Averages over							
		8 years, 1844–1851	10 years, 1852–1861	10 years, 1862–1871	10 years, 1872–1881	10 years, 1882–1891	10 years, 1892–1901	10 years, 1902–1911	60 years, 1852–1911
		Bush.	Bush.	Bush.	Bush.	Bush.	Bush.	Bush.	Bush.
2	Farmyard manure	28·0	34·2	37·3	28·7	38·2	39·2	35·1	35·5
3	Unmanured	17·2	15·9	14·3	10·4	12·6	12·3	10·9	12·8

We may now turn to one of the other plots which receives an excess of farmyard manure each year, the manure supplying about 200 pounds of nitrogen per acre, whereas the crop only takes away about 50 pounds. Naturally the land in this case increased in fertility, but after twenty or thirty years another position of equilibrium was attained at a level of about 36 bushels per acre, after which, despite the continued additions of manure, the crop again did not vary except as the result of exceptionally favorable seasons. If we now consider a similar balance-sheet for this plot, we find that the additions of nitrogen are balanced neither by the removals in the crop nor by the accumulation of nitrogen in the soil; indeed half of the nitrogen applied is unaccounted for. The soil has been getting no richer for the last twenty or thirty years, and the greater part of the nitrogen is wasted, doubtless because bacterial action sets the nitrogen free as gas. Here, then, we see another principle illustrated, that in very rich land the wasteful agencies are so speeded up as to prevent any continued accumulation of fertility out of the unused residues of the manures put on. Higher fertility means a higher level of waste, and this explains the rapidity with which the very rich virgin soils lose their fertility when they are put under arable cultivation. In this Rothamsted plot, the soil of which still contains less nitrogen than the less rich virgin soils of the prairies, three times as much nitrogen are wasted every year as is converted into crop, and the same or an even greater rate of wastage must attend the conversion of the rich virgin soils into land growing a succession of cereal crops.

BROADBALK WHEAT FIELD.

Nitrogen in Soil, Pounds Per Acre.

In soil, 1865	In soil, 1904	Gain or loss in 39 years	Added in manure	Added in rain	Removed in crop	Unaccounted for
Plot 3.—Unmanured.						
2850	2290	−560	...	150	600	−110
Plot 2.—Farmyard Manure.						
4470	4970	+500	7800	150	1990	−5460

We may now turn to another plot on the same field to illustrate the recuperative actions of which I have spoken. This is a part of the field that has been running wild since 1881, when the wheat it carried was not harvested, but allowed to seed itself. A very few years sufficed to eliminate the wheat, which was unable to maintain itself against the competition of the weeds, and the land now carries a miscellaneous vegetation consisting mostly of grass. A soil sample was taken at starting, and when compared with another sample taken twenty-three years later showed that in the interval the land had gained nitrogen at the enormous rate of 92 pounds per acre per annum. Making every allowance for possible errors in sampling and analysis, the accumulation of nitrogen is in marked contrast to its steady depletion in the equally unmanured arable land alongside. Now, the difference between the two plots lies in the fact that on the land running wild the vegetation is never removed, but allowed to die down naturally. Hence not only is the nitrogen taken out by the crop returned to the soil, but also a large stock of carbonaceous matter assimilated from the atmosphere, and this carbonaceous matter furnishes a bacterium present in the soil, *Azotobacter chroococcum*, with the source of energy which will enable it to fix atmospheric nitrogen. Azotobacter is equally present in the soil of the unmanured wheat plot; but, as there the crop is removed and only a little root and stubble left behind, there is but little carbonaceous matter for the Azotobacter to work upon, and a correspondingly small fixation of nitrogen, sufficient only, as we have seen, to repair the casual losses by drainage and weeding. This plot gives us a clue to the source of the vast

BROADBALK FIELD, ROTHAMSTED.

Land allowed to run wild. Nitrogen in Soil, pounds per acre.

—	In soil to 27 in.		Added by rain	Gain in soil per annum
	1881	1904		
Broadbalk	5910	8110	90	92

* A discourse delivered at the Royal Institution on Friday, May 24th, by A. D. Hall, F.R.S.

accumulations of nitrogen in the old prairie soils. Vegetation alone, however long continued, cannot increase the stock of nitrogen in the soil; there is only a circulation of the initial stock removed by the plants and then put back when the plant dies *in situ*. But if the conditions are also favorable to the development of Azotobacter, this organism derives from the carbonaceous part of the plant residues the energy it requires for the fixation of nitrogen, and a steady addition to the original stock goes on. We have found Azotobacter present in all these rich black soils, from both South and North America, the Russian Steppes, and similar virgin land in all parts of the world, and again we also find an abundance of lime, one of the other necessary factors for the growth of Azotobacter. Virgin soils are not necessarily rich; there are miserably poor ones, though they have equally carried some sort of vegetation for hundreds, indeed thousands of years. They have remained poor because some of the other factors upon which depend the development of Azotobacter are lacking. With this far-reaching conclusion in sight, we have naturally tried at Rothamsted whether we could not bring about a similar heaping up of nitrogen in the soil by simply adding to it a carbohydrate containing no nitrogen, such as starch or sugar. In pots, the experiment is perfectly successful, and accordingly we selected one of the plots in the barley field which was in a very nitrogen-starved condition, because it had been manured for fifty years only with mineral fertilizers containing no nitrogen, and treated half the plot with sugar at the rate of a ton to the acre, the other treatment of the two halves of the plot being alike. To our surprise, the half receiving sugar gave a miserable crop, much below the non-sugar half, for four years in succession, and a bacteriological examination of the soil showed that Azotobacter had not increased in response to the sugar, but that the number of merely putrefactive organisms had gone up greatly. These facts led Dr. Hutchinson to surmise that we had been putting on the sugar at the wrong time of year, in early spring or winter, some time before the barley was sown, when the soil is cold. Now Azotobacter is comparatively inactive at low temperatures, and the sugar was probably being wholly taken by the Steptothrix, etc., which are less affected by cold. As these organisms must also obtain nitrogen, they were robbing the barley of the small stock available in the soil, and so bringing about the observed reduction of crop. A change was accordingly made in the time of application of the sugar, which was put on as soon as the barley had been harvested, when the soil still retained its summer heat, and the change was immediately followed by an increase in the succeeding barley crops, as compared with the non-sugar plots, that was as marked as the deficiency had been previously. This illustrates the many pitfalls which attend investigations in agricultural science. Under laboratory conditions one can define the issue sharply, but as soon as the experiments are extended to the open ground and living plant, so many extraneous and unsuspected factors come into play that what is popularly called a conflict between theory and practice often becomes apparent.

HOOSFIELD BARLEY.

Effects of Sugar (or Starch) on the Amount of Produce. Plot 4 O. Complete Minerals.

Year	Sugar (or starch) applied	Total produce of barley	
		Without sugar	With sugar
		lb.	lb.
1906	Spring	2485	[2]
1907 [3]	,,	3578	3249
1908	,,	1820	1404
1909	,,	2563	2261
1910	Autumn	2082	2502
1911	,,	1244	1915

[2] Very small crop, not weighed.
[3] Starch applied instead of sugar in 1907.

We may now take a more complex example from the Rothamsted plots to illustrate what I have called the conservative systems of farming. One of the fields is farmed on a four-course rotation of turnips, barley, clover, wheat, but over half the field the clover is replaced by a year's bare fallow. Further, if we confine our attention to the one plot which never gets any nitrogen, but only mineral fertilizers, it is again divided at right angles into plots from which the turnip crop is wholly removed, and others on which it is returned, as so often occurs in practice when the turnips are eaten off *in situ* by sheep.

NITROGEN PER CENT IN SOIL OF AGDELL FIELD, ROTHAMSTED.

The Plots Receive Mineral Manures, But no Nitrogen.

	Fallow		Clover	
	Roots carted off, 13/14	Roots returned, 0/10	Roots carted off, 15/16	Roots returned, 1:/12
1867	0·1224	0·1240	0·1327	0·1380
1874	0·1147	0·1238	0·1241	0·1321
1883	0·1161	0·1228	0·1329	0·1383
1909	0·1159	0·1195	0·1347	0·1498
1852–1903				
Wheat, average	31·2 bush.	32·2	32·2	35·1
Clover ,,	—	—	41·0 cwt.	47·7
Swedes ,,	151 0 cwt.	268·0	160·0	187·0
Barley ,,	22·1 bush.	28·7	24·5	34·5

The above table shows the average yield on these plots and also the changes in the nitrogen content of the soil at different dates.

There are two possible recuperative actions to make up for the crops removed—the Azotobacter working upon the carbonaceous matter returned in the turnip crop, and the growth of the clover, for that crop, as we know, gathers nitrogen from the atmosphere by means of the organisms living in the nodules upon its roots. When neither clover is grown nor are the roots put back the soil is slowly losing nitrogen; when either occurs singly a fair production is maintained without loss of soil nitrogen; when both take place during the rotation the average removals from the soils become as high as thirty-five bushels per acre of wheat, thirty-four of barley, and more than two tons of clover hay, yet the soil is, if anything, gaining rather than losing in fertility, though no extraneous nitrogen is being introduced.

Thus we see that we can maintain indefinitely a production of more than four quarters per acre of wheat, and their equivalent in other crops, by natural agencies alone without recourse to external supplies of nitrogen, provided we repair the small annual losses of phosphoric acid and potash, which, of course, cannot be regenerated from the atmosphere. But such a level of production, though equal to the average of the British Isles, is below that which a modern intensive farmer must attain, and the lesson that we have to bear in mind is that at a higher level, say that of five quarters of wheat, the wasteful actions of which we have spoken are increased out of all proportion. Hence we have to add as manurial nitrogen not merely the difference between that contained in the extra quarter of wheat, but four to five times that amount to repair the waste, and so on to an even greater extent if we still further raise the fertility and the production.

The essential wastefulness of highly intensive agriculture such as must be forced upon the race as the new countries fill up is a serious question, but the prospect of reducing the waste is not entirely hopeless. The losses, as we have seen, are due to bacteria, which attack the nitrogen compounds with liberation of nitrogen gas, the particular bacteria doing this being most active in soils rich in organic matter, until at Rothamsted we only recover in the wheat crop about one quarter of the nitrogen applied in the heavy dressing farmyard manure. The problem before us is to bring the soil bacteria under control, and we already begin to see in various ways that such control is not impossible. For example, the researches of Drs. Russell and Hutchinson at Rothamsted have already proved that in one simple way we can so rearrange the microfauna and flora of the soil as to obtain a much higher duty from the reserves of nitrogen therein contained.

It is too long a story to enter upon now. I can only briefly say that by putting the soil through various processes of partial sterilization, such as heating or treatment with antiseptics, like chloroform or toluene, we can eliminate certain organisms which keep in check the useful bacteria in the soil—i. e., the bacteria which break down the nitrogen compounds to the state of ammonia, a form assimilable by plants. Heating the soil to the temperature of boiling water for two hours will double its productivity, and such a process has been found to be commercially profitable in the case of greenhouse soils. The market growers of cucumbers and tomatoes make up an exceptionally rich soil of virgin loam and stable manure, but in a few years such soil, while still enormously rich on analysis, becomes incapable of growing a profitable crop. The partial sterilization processes of which I have been speaking restore and even enhance its fertility by eliminating the injurious organisms, and we learn from the detailed results that after such treatment a much larger percentage of the soil-nitrogen is recoverable in the crop than normally prevails in untreated soil. At present the processes have not been extended to the open field, but progress is being made in that direction, and gives some promise of a method by which ultimately the unseen fauna and flora of the soil will be domesticated, the useful races encouraged, and the noxious repressed, just as the larger flora and fauna have been reduced to our service since the days when primitive man first turned from hunting to agriculture.

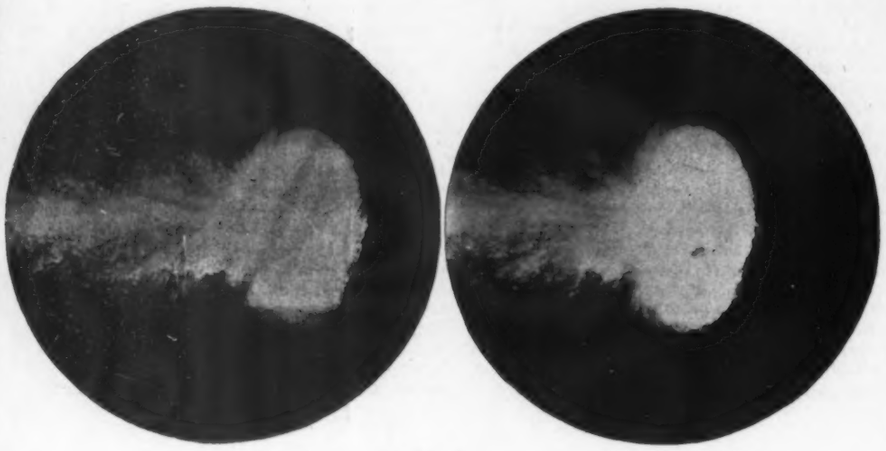
Power Transmission from the Coal Mine

TRANSMISSION of electrical energy direct from the mouth of the coal mine to the consuming market for lighting and power service has long been recognized by engineers as a genuine method of conserving natural resources. The problems of such transmission are of much interest from the standpoint of station design and operation, and although they tend to become somewhat specialized in view of the peculiar conditions controlling the fuel supply, they are well worthy of the consideration of power economists.

A pioneer installation of this type in America is the Chignecto plant, located in the bituminous mining district of central Nova Scotia, about eight miles from the manufacturing town of Amherst. In this case a generating station of 1,000 kilowatt rating is located at the pit mouth, and the energy latent in the slack or refuse screenings is electrically transmitted to Amherst and also to the mining district of Joggins, on the Bay of Fundy, service being tapped off at the intermediate towns of Maccan, Nappan and River Herbert. The transmission lines are operated at 11,000 volts, a modest pressure in these days of wide-radius electrical distribution, but adequate for the distances and loads involved in the Chignecto district, Joggins, the most remote center of distribution, being but fifteen miles from the power house. The service includes the supply of electricity for lighting throughout each of the towns reached by the lines of the company, a commercial power business including the operation of a gypsum quarry at Nappan, the driving of factory machinery in Amherst and the running of pumps, blowers and other apparatus at the mines. Continuous service is maintained, giving the towns supplied an advantage not possessed by many small Nova Scotia communities which receive electricity only at night from their small local plants.

The use of low-grade fuel is the most interesting phase of the Chignecto development. Screenings are discharged, without any attempt at their separation from dirt, slate, etc., upon a conveyor leading to a coal bunker in the boiler room, where eight 150-horse-power horizontal return tubular units equipped with underfeed mechanical stokers supply the steam required by the main generating sets and their auxiliaries. Both natural and forced draft are in use, the latter being, of course, necessary with the type of stoker employed. Either of two sets of blowers is sufficient to give 5 inches of draft in the ash pit with all the boilers in operation. On account of the poor quality of the fuel the grate areas are made considerably larger than usual, the figure for each boiler being 49 square feet. Steam is also supplied at the bank head of the mine for hoisting, the service from the power house having shut down an old boiler plant and eliminated the usefulness of two firemen, a machinist and helper. Making due allowances for the steam delivered to the mine the fuel consumption of the plant is about 6.5 pounds per kilowatt-hour delivered at the busbars. The fuel contains 20 per cent ash, and the station payroll covers a total of ten men, most of whom are occupied on the boiler room side of the plant. The engines are of the vertical, cross-compound condensing type, and special care is taken to use water economically, the supply for all purposes being drawn from a small creek with some artificial storage and provision for returning the condensate to a pond above the power house through a cooling tower.

The plant illustrates the reclamation possibilities of electricity in dealing with an otherwise unmarketable fuel, 30 per cent of the mine output being worthless for selling purposes and removable from the locality only at a prohibitive cost. The saving in converting this cheap grade of fuel into electrical energy is much greater than if a good quality of coal were used. The present load factor of the plant is about 72 per cent on a 24-hour basis. The labor requirements are doubtless increased considerably by the care needed in the burning of the poor fuel available, it being necessary to clean the fires every two hours. A plant burning high-grade fuel at the pit mouth with mechanical stokers and a practically unlimited water supply would probably show a lower labor cost and a smaller investment, but the present installation is understood to be generating power at a cost no greater than is possible in a hydro-electric plant of about the same size. It furnishes an excellent example of by-product waste utilization which may well be favorably considered in other mining localities situated within striking distance of desirable markets for the sale of electricity at reasonable rates.—*The Engineering Record.*



View A.

An Experimental Stu of in Liqui s—

Lord Kelvins's Smoke-r Mo

By Prof. Edwin F. Northrup, Ph. D., Palme hysic

Concluded from SCIENTIFIC AMERICAN Supple No. 1

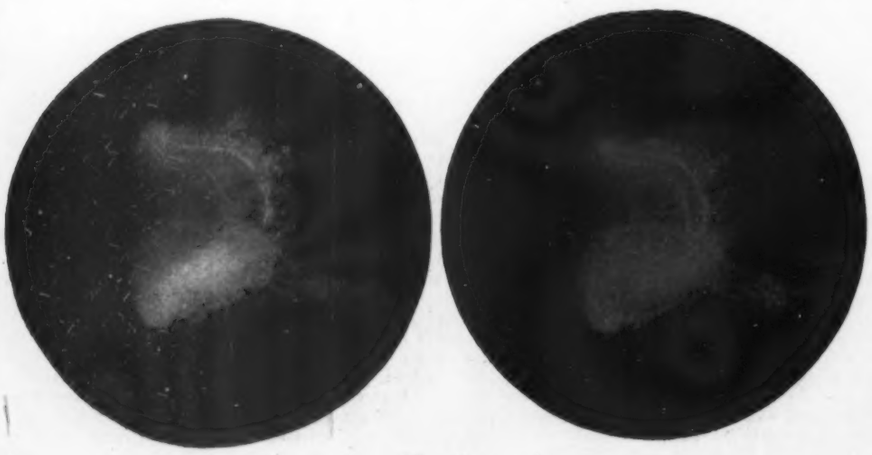
VIEWS of rings at the moment when changing from water into oil, and at the moment of reflecting from an oil or water surface, might have been obtained by a sufficient expenditure of time and care.

From necessity the photographs were taken of the rings viewed very nearly edgewise; that is, normally to their direction of motion through the tank. It would have been interesting if views could have been secured through the lens in the end of the tank. These would have shown the rings as they appear when approaching the observer. The problem of illumination, however, was difficult, and no serious attempt was made to solve it. It was at first thought that milk-white rings might be sufficiently illuminated to be photographed by reflected light, but when this was tried with white rings of silver chloride they were found to phosphoresce for too long a time to enable instantaneous photographs to be taken, even had the illumination been sufficient, which is doubtful.

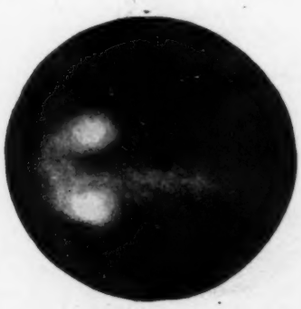
View A, reproduced to be viewed in a stereoscope, is of a single ring, distant a few centimeters from the gun. It has at this point a characteristic mushroom appearance and is followed by a trail of color. This ring, when photographed, was moving about one and a half meters per second. In View K is shown another ring which has also just left the gun. It probably started with a higher velocity than the ring shown in the previous view, and its mushroom head and trail present a smoother appearance. View L shows a ring which has gone about 30 centimeters from the gun. It started with the same appearance as the ring in View A. The trail has entirely disappeared. It also is moving more than a meter a second and is about to strike a small watch chain suspended vertically in the water. View B is of another ring taken under conditions similar to the conditions under which the ring in View L was taken. View C is of another ring, a greater distance from the gun, in which the coloring matter is less dense. If carefully observed, small dark particles may be seen to be distributed along the filamentary axis of the ring. The position of these particles does not clearly appear in a single view, but when a double view is observed in a stereoscope they are plainly seen to lie along the axis of the ring. In many of the views this line of dark particles is shown very clearly. While it was supposed that the coloring matter of the ring was free from suspended particles, some must have been present originally in the ring or were gathered up by it in its progress through the water. As a vortex ring throws off particles denser than the material of the ring itself, particles which are retained in a water ring must have a density of less than water. In O we have three views, slightly smaller than the others, of the same ring, taken about 1/50 of a second apart, showing the ring just before and just after it has struck the chain. View M shows remarkably fortunate timing. The ring has moved up to, but has not actually struck, the chain. It will be noted that the chain bulges most on a line from the center normal to the plane of the ring. The filamentary core of dark particles also shows well in this ring. The core, can generally be seen only in rings which are but slightly colored.

When the diaphragm of the gun is provided with two circular holes, one above the other, two rings are ejected at the same instant. The action upon each other of the two rings ejected is, perhaps, the most interesting property of these vortices. To study this action a large number of exposures of double rings were made and a few very instructive negatives secured. These views were all taken stereoptically, and to learn all they teach should be viewed in a stereoscope. Negatives

View C.



View F.



View G.

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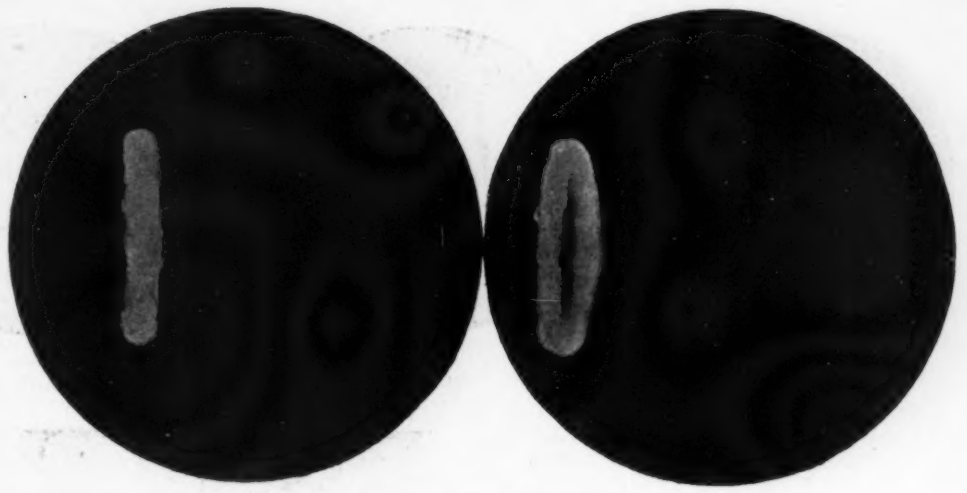
al Stu of Vortex Motion Liqui s—IV*

s Smoke-r Model of the Atom

Ph. D., Palm hysical Laboratory, Princeton University

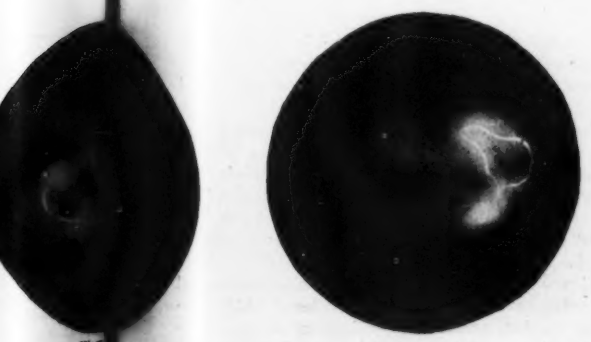
MERICAN SUPPL No. 1919, page 239, October 12, 1912



View B.

were obtained of the double rings just as they were leaving the gun and also at different distances up to half a meter. In View E double rings are shown which have issued about five centimeters from the gun. There is less coloring matter in the upper ring than in the lower, which permits the internal construction of the upper ring to be more clearly seen. Both rings have the mushroom appearance characteristic of single rings just issuing from the gun. There is already an indication in this picture that the two rings are being attracted toward each other, and their planes are seen to be slightly tilted in the direction of their forward motion. The next view, D, shows two other rings a few centimeters farther from the end of the gun. The attraction toward each other and the tilting of the planes of the rings are here still more pronounced. In the following view, F, are shown two other rings a centimeter or two farther from the gun than the previous pair. Here the attraction has become so great that the rings have joined. The dimly-seen cores of the separate rings, now become a single ring, show a peculiar outline, somewhat like the letter C, when viewed from a position at right angles to the forward motion of the ring. In View N the two rings have completely joined, but their trails extend back along the separate paths which they had previously followed. View G gives a slightly later stage of a double ring. In View H the vortex has become a distorted ellipse, with major axis normal to the plane of the paper. View I also shows a newly-formed double ring. View J is a ring in which the joining of the two separate rings is completed. Its phase of vibration is such that it is convex upon the side facing its direction of motion. It should be noted that the vortex has become cleared of all surrounding coloring matter. In View P is shown another ring, also made up of two separate rings, as it appears in three successive stages separated by intervals of about 1/50 of a second. Here are plainly seen the four kinds of motion possessed by liquid vortices which have been formed from the union of two single rings. First, there is a rotation about the vortex filament; second, the forward motion of the vortex as a whole; third, a motion of oscillation of the extremities of the vertical diameter of the vortex in a vertical plane lying parallel to the direction of forward motion; and fourth, a motion of oscillation of the extremities of the horizontal diameter of the vortex in a horizontal plane parallel with the line of motion of the vortex. These four motions, except the second, are too rapid to be observed satisfactorily with the eye. But the instantaneous photographs here reproduced fairly demonstrate the nature of these motions, and the stereoscopic views especially enable their character to be accurately observed.

View E.



View I.

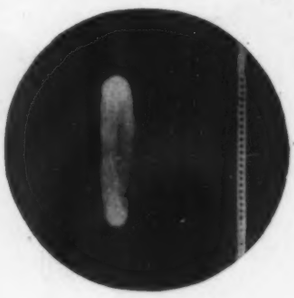
View J.

PHYSICAL EXPLANATIONS OF VORTEX MOTIONS.

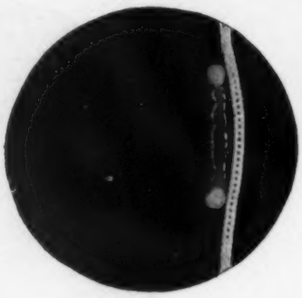
Various physical and mathematical treatments of vortex motions that have been given by Helmholtz, Lord Kelvin, Lamb, J. J. Thomson, and others, are based, in the main, upon the assumption that the medium in which the vortices exist is a so-called "perfect fluid." In Thompson and Tait's "Natural Philosophy," vol. II, sec. 742, the definition given for a perfect fluid is as follows: " . . . a body incapable of resisting a change of shape; and, therefore, incapable of experiencing distorting or tangential stress. Hence, its pressure on any surface, whether of a solid or of a contiguous portion of the fluid, is at every point perpendicular to the surface." In sec. 320, vol. I, the same authors say, " . . . a mass which is absolutely incompressible, and absolutely devoid of resistance to change of shape, is given the simple appellation of a liquid."

A *liquid* of this character, which is an incompressible fluid, is the ideal or perfect liquid of the mathematician. A *fluid* may be perfect and yet be a compressible fluid in which the density is a constant function of the pressure. Water does not fulfil Kelvin's definition of a perfect liquid, chiefly because of its viscosity. It is, however, nearly incompressible and relatively free from internal

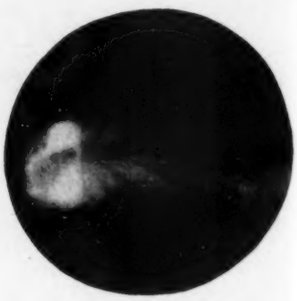
View K.



View L.



View M.



View N.

friction, and therefore is the most suitable of any known liquid for the experimental study of vortex motions.

Vortex motions may be studied from two diametrically opposite points of view: the mathematical and the experimental.

From the former the mathematician attempts to deduce from a few fundamental assumptions the nature of vortex motions in a so-called perfect fluid and then to predict how the viscosity of actual fluids will modify these motions.

From the latter the experimentalist observes the motions in actual fluids and then reasons how they might become modified if the viscosity were to become indefinitely small. The experimental method was chosen because it is better within our capabilities and because it was believed that all actual physical problems are more likely to find their solutions when actual rather than ideal types of matter are dealt with.

The purely physical explanations, which follow, of the nature of the motions of vortices in actual liquids, may not accord in all cases with the conclusions of mathematical examinations of motions in assumed perfect fluids.

In a perfect fluid, according to the mathematicians, a vortex can never be created, or, if in existence, it cannot be destroyed. In water the vortex is easily formed and easily destroyed, while the manner of its formation is not difficult to understand.

The creation of vortices in actual fluids, their mutual action upon each other, and many peculiarities of their motions are explicable by the application of a theorem announced by Bernoulli in the 18th century. The meaning of this theorem should be clearly understood as a preliminary to any physical explanation of vortex motions.

Let the attention be fastened upon a single cubic centimeter of the liquid in the tank. Let this single cubic centimeter be h centimeters below the surface, and let the density of the liquid in the tank be d, then the mass of the single cubic centimeter will be d grammes. If g is the acceleration of gravity, the weight of this cubic centimeter will be $g\ d$ dynes. Now if the imaginary cubic centimeter of liquid were lifted from its position h centimeters below the surface to the surface, the quantity of work done would equal $h\ g\ d$ ergs. Or, if we conceive the cubic centimeter of liquid replaced by a massless cube one centimeter along each edge, the work done by the rest of the liquid in raising this cube to the surface would be, as above, $h\ g\ d$ ergs. Hence the potential energy of this cubic centimeter of fluid is,

$$P_p = h\ g\ d.$$

Next conceive this same cubic centimeter of liquid to have a velocity in any direction of v centimeters per second. It would then have a kinetic energy $\frac{1}{2}\ d\ v^2$. The imaginary cubic centimeter of liquid also has additional potential energy, due to the fact that the liquid of the tank is under atmospheric pressure. This potential energy will be readily understood if we conceive a fine tube to have one end in the center of the imaginary cube of liquid and its other end in a vacuum. The imaginary cube of liquid, if located at the surface of the liquid, would tend to flow into the vacuum with a force depending upon the pressure of the atmosphere. The potential energy due to this cause alone is simply the pressure per square centimeter upon the surface of the liquid. Call this energy p. These last statements become clear by considering that the work required to force a volume V of liquid from the vacuum back into the tank is pV. The area of the piston, multiplied by p, is the force, and the product of the force by the length of the stroke is $p\ V$, and is the work done. Hence if V is made a unit volume the work is p; that is, the potential energy due to the pressure on the liquid, per unit of volume, is simply p.

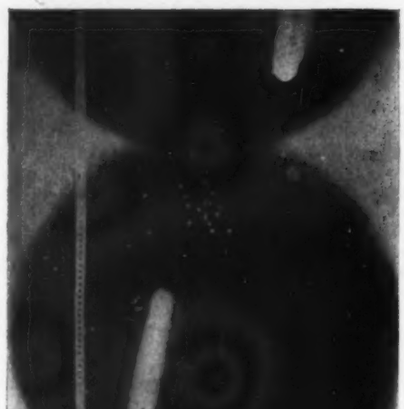
By the principle of the conservation of energy, the sum of the potential and kinetic energies of any portion of the fluid (friction neglected) must remain constant. Hence we have

$$p + g\ d\ h + \tfrac{1}{2} d\ v^2 = H, \text{ a constant.}$$

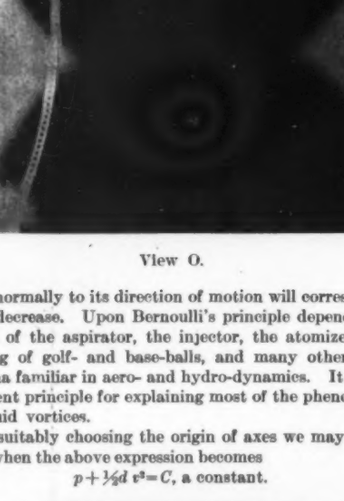
This important relation, known as Bernoulli's theorem, is to the effect that, if at any point in a fluid the velocity of the fluid increases, the pressure which the fluid will exert normally to its direction of motion will correspondingly decrease. Upon Bernoulli's principle depends the action of the aspirator, the injector, the atomizer, the curving of golf- and base-balls, and many other phenomena familiar in aero- and hydro-dynamics. It is the sufficient principle for explaining most of the phenomena of liquid vortices.

By suitably choosing the origin of axes we may write $h = o$, when the above expression becomes

$$p + \tfrac{1}{2} d\ v^2 = C, \text{ a constant.}$$



View O.



View P.

Let us consider, with this principle in mind, what happens when the diaphragm of the gun is struck a blow (Fig. 12). The diaphragm moves suddenly from p to p_1, and the streamlines of the liquid, outside the orifice, will be somewhat as indicated in full lines. After the liquid has issued from the orifice it might have been expected to move as indicated in dotted lines. Instead, however, the stream-lines of its flow bend into spirals, as roughly indicated by the heavy lines, every particle moving toward a point where the pressure is diminishing. Now it is evident, from Bernoulli's principle, that at the edge of and just outside of the orifice the velocity of the liquid will be high and the side pressure low; hence any particle which has reached a position as a will be urged not from but toward the edge of the orifice, and move in a curved path approximately circular. The ring once formed continues to move forward, and the particles of liquid in it rotate rapidly about a circular center called the vortex filament. At the beginning of motion, however, an additional body of liquid is carried along with the vortex, which is afterward left behind as a trail. The general contour of this additional body of liquid is shown in Fig. 12 by the broken heavy lines. It is due to this that a vortex possesses the peculiar mushroom appearance shown in Views A and K, taken shortly after it has left the gun.

After the ring is completely formed we have the case of particles of fluid in rapid rotation about an axial line, and the query naturally arises, why the substance of the ring is not thrown off tangentially by the action of centrifugal force.

Such, indeed, would be the case if the vortex filament did not form a closed loop. If the substance of the ring were thrown off by centrifugal force it would of necessity be replaced by other portions of the liquid. Now as the ring is closed upon itself, and as centrifugal force acts equally at every tangent to a cross section, there is as much tendency for the particles of the ring to leave at one point of its surface as at another, and so even should a particle leave at a given point there would be no tendency to its replacement by a particle leaving at another point. Furthermore, as the velocity of the particles at the circumference of the ring is high, there will be, by Bernoulli's principle, a radial pressure acting toward the filament of the vortex.

If the attempt be made to form a vortex of a more dense fluid in a less dense one, as a vortex of carbon-tetrachloride in water, a condition of instability exists, and the more dense particles of the vortex actually do fly off, impelled by centrifugal force. If a vortex ring is moving through water, filled with finely-suspended particles, as ground Indian meal, denser than water, it will not pick up the particles. If, however, the suspended particles are less dense than water they will be swept into the vortex and carried along with it.

It is on this principle that oil rings are formed out of water rings. Assume a layer of oil on top of the water in the tank. When a water ring is made to enter the less dense oil, centrifugal force throws out the water, scattering it, and the oil is drawn in to take its place, thus forming a complete oil ring. This ring moving toward the surface of the oil will on reaching the surface be deflected and, re-entering the water, will continue to move as a stable ring of oil. As one of these oil rings is about to break up, the oil of the ring separates into small globules, which are plainly seen whirling in circular orbits about the vortex filament as an axis, in apparent contradiction to the law of centrifugal force.

The fact that liquid vortices react upon each other, and are able to cause motions in solid matter (see View M) before there is actual contact of the vortex with the solid matter, proves that the rings are surrounded by what may properly be termed a "field of fluid motion." This field consists of a system of stream-lines of moving liquid. It may be represented by drawing in the fluid an imaginary system of lines, similar to those employed for representing a magnetic field of force which surrounds a circular conductor carrying an electrical current. About the ring the fluid at any instant has a perfectly definite motion. It is this definite motion

of the fluid, outside of the ring, which constitutes the field of fluid motion about the ring, which can react upon a similar field surrounding another ring. If, therefore, at every point in the fluid surrounding the ring lines be drawn in the direction of the motion of the fluid at a given instant, and if at all points in the fluid the number of lines drawn per square centimeter of area, taken normal to the direction of the lines at such points,

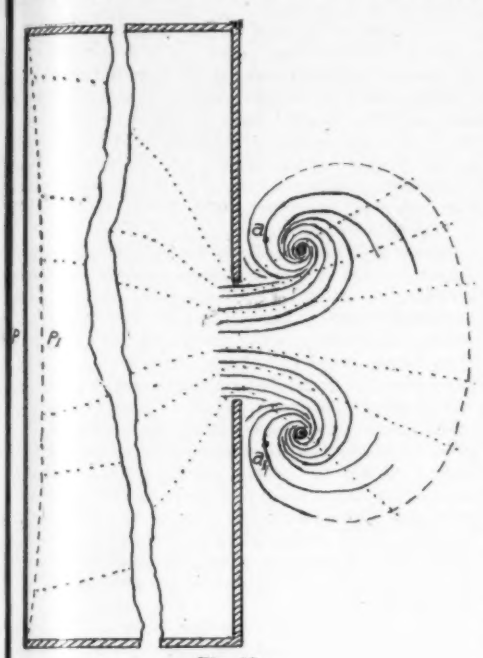


Fig. 12.

be made equal in number to the velocity of the fluid, then this system of lines will represent, both in direction and magnitude, the instantaneous fluid motion at every point in the field.

The purpose of this article being only to record experimental results, no mathematical treatment of vortex motions will be attempted. Those interested in this phase of the subject are referred to Chapter VII of Lamb's "Hydrodynamics," third edition. A few physical conceptions may be given here, although these conceptions are confessedly somewhat hypothetical.

Imagine a cricular vortex ring to have for an instant no forward motion. The system of lines drawn to represent the field of motion about the vortex are then assumed to be identical in form and distribution with that which would be required to represent the magnetic field of force about the ring, if it were made to carry an electric current flowing along the filamentary axis and uniformly distributed throughout the cross section of the ring. But all rings, as actually observed, have a rapid forward movement which greatly modifies the distribution of the system of stream-lines as assumed above. In actual rings some of the fluid which surrounds it is carried forward with the ring as it moves through the fluid. The general form of the body of fluid which moves with the ring is that of an oblate spheroid and gives to the ring the mushroom appearance well illustrated in View A. In View D of two rings the color of the upper ring is sufficiently pale so that the true vortex is visible within the spheroidal body of liquid which is moving with it. This spheroidal body of liquid is gradually left behind, in a liquid, like water, having viscosity, and is visible as the trail. As the ring progresses the oblate spheroid of colored liquid becomes gradually replaced by colorless liquid, and when this interchange of colorless liquid for colored is complete the oblate spheroid becomes invisible and the colored vortex only is seen. It then appears as a colored ring, shown in Views L, B, and C. These older rings, in all probability, still carry a body of liquid with them.

This is being drained off and replenished in exactly the same manner as appears in Views A and D.

Diagram, Fig. 13, is constructed on the assumption that the fluid has no viscosity. In it the direction of the lines represents the direction of motion of the fluid, and the density of the lines the velocity of the fluid. This velocity is reckoned in reference to the ring itself; that is, the axes of reference must be considered as having their origin located at the center of the ring and to move with the ring. The portion of fluid within the two small circles constitutes the true vortex, which retains its color and visibility after the surrounding portion has exchanged all its colored liquid for colorless liquid. The portion of the fluid within the elliptical line, which is a cross section of an oblate spheroid, is the portion of fluid which moves forward with the ring. If the fluid were without viscosity the ring would leave behind it no trail; that is, the same fluid contained in the oblate spheroid with which the ring started on its journey would remain with it to the end. In the actual case this body of fluid is being gradually drained off and replenished until all visibility disappears, except for the vortex itself.

Any small particle, as at *P* (Fig. 13), if more dense than the liquid, is not caught up by the ring when the ring approaches it, but is pushed aside by the body of fluid which the ring carries with it, and receives, when the ring approaches and passes it, a small to-and-fro motion. A cord or chain suspended in the fluid, as indicated by the line *c*, *c*, is curved forward before it is actually reached by the ring. The View M shows this well.

With the above in mind it is not difficult, aided by the photographic views, to explain the union and subsequent double vibratory motions of the rings. For this explanation reference is made to some purely diagrammatic views given below.

In Fig. 14 *a* shows two rings a few centimeters from the gun. They are shown in side view, moving in

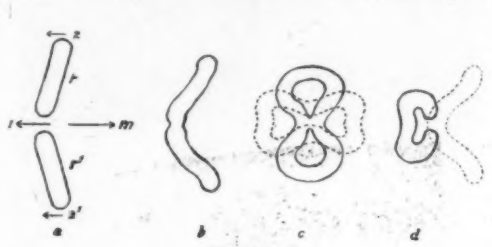


Fig. 14.

the direction indicated by the arrow *m*. The velocity of the fluid *in reference to the rings* is indicated at three points by the arrows 1, 2, 2^1. Since this velocity is greater at 1 than at 2 and 2^1, the points on the circumferences of the rings which are adjacent lag behind the points which are opposite, and consequently the planes of the two rings begin to tilt forward in the manner indicated.

Furthermore, as the velocity of the fluid is greater at 1 than at other points equally distant from the filaments of the rings, there will be acting a pressure, according to Bernoulli's principle, which will tend to force together adjacent points of the circumferences of the two rings. Hence, a moment later the rings will assume a position as indicated at *b*. The rings should now be viewed from behind, when their form will be (at a very brief instant later than shown in *b*) as indicated in full line at *c*, or in dotted line at *d*, which is a side view. The high velocity of the fluid at the point of contact has caused the two rings to unite and assume the form of a figure 8, with its upper and lower ends greatly tilted forward in the direction of motion of the now single ring.

As this distorted single ring has everywhere an equal tension along its filamentary line, it tends to assume a circular form and lie in a plane normal to the forward direction of motion. But in changing its form to assume the circular plane ring form it overshoots this equilibrium position and assumes, as seen from behind, the form shown in dotted line at *c*, and as seen from the

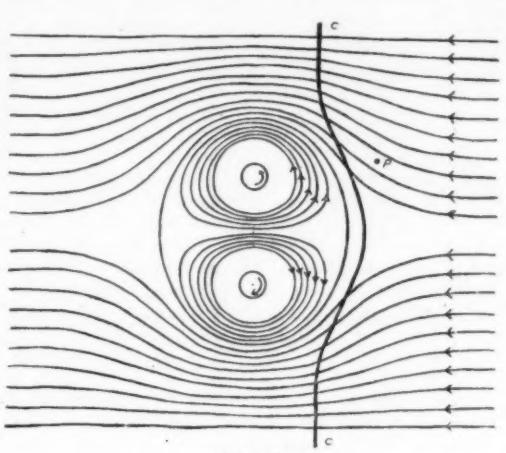


Fig. 13.

side the form shown at *d* in heavy line. This double oscillation about the form of equilibrium now continues, and the ring advances, its form rapidly changing in the manner which the View P beautifully reveals.

The inquiry naturally arises: Would two rings existing under similar circumstances, in a perfect fluid, or in the luminiferous ether, join together? If two vortices can unite, then would not these in turn join with others? If such be the case for perfect fluids, then it follows that a system of electrons or atoms constituted of vortices, in a perfect fluid, would not preserve their identity, but would form unions which would ultimately destroy any distinctive existence which the vortex atoms or electrons might possess.

These are questions upon which further experimentation would throw much light and the experimental facts obtained would constitute a proper basis for, and check upon, mathematical investigations regarding perfect fluids.

The above-described experiments were begun at the laboratory of The Leeds and Northrup Company, Philadelphia, Pa., in April, 1909, and were later carried on and completed in January, 1911, at the Palmer Physical Laboratory, Princeton, N. J. When working at the first-mentioned place, the writer was ably assisted by Mr. William Wrighton, in charge of the experimental work of The Leeds and Northrup Company, who spent much time on the research, solely for the scientific interest he felt in it. At the latter-mentioned place the writer was much assisted, especially in the photographic work, by Mr. Phillips Thomas. To both of these gentlemen the writer extends his grateful acknowledgements.

Sinhalese Iron and Steel of Ancient Origin—III*

Beginnings of the Iron Age

By Sir Robert Hadfield, F.R.S., Sheffield

Continued from SCIENTIFIC AMERICAN SUPPLEMENT No. 1919, page 235, October 12, 1912

IV.

DELHI AND DHAR PILLARS IN INDIA.

One of the most notable ancient specimens of iron is the famous Pillar of Delhi, which is not the less interesting when we find it is stated that the city itself, "Imperial Delhi, the capital of all India," as Sir Alexander Cunningham in 1864 termed it, owed its name to this pillar. In the light of recent political events, this prophetic utterance is now an actually accomplished fact, for on December 12th, 1911, Delhi was made the capital of our great Indian Empire. We have also this remarkable chain of circumstances. Delhi took its name from the very pillar now described, the Hindoo term being "Delhi," or unstable, as explained later on. At Delhi, King George V., the first English monarch to be present in person, has been proclaimed Emperor in Dhurbar, and, finally, Delhi is now the seat and actual "Capital of all India."

Ancient associations, historical and legendary, combine to invest Delhi with exceptional dignity in the eyes of both Hindoo and Mohammedan Indians.

In the official Government despatches of last year, it was stated that "Delhi is still a name to conjure with; it is intimately associated in the minds of the Hindoos with sacred legends which go back even beyond the dawn of history."

As shown in this paper, seeing that Delhi itself takes its name from the Iron Pillar, and that it is now the capital of our Indian Empire, with its 300,000,000 of inhabitants, this particular article of iron is of more than ordinary interest to the members of our Institute. In view of its importance, what follows may therefore be of interest. There was formerly a plaster cast or model of it in the Victoria and Albert Museum in 1873. The author spent some time in trying to find this at South Kensington, but finally discovered that it was unfortunately destroyed during a fire in 1885,

*Excerpts from a paper read before the Iron and Steel Institute, May 9th, 1912, and published in *Engineering*.

and up to the present time, has never been replaced.

In the "Archæological Survey of India," page 169 (four reports made during the years 1862 to 1865), Sir Alexander Cunningham, C.S.I., etc., states that one of the most curious monuments in India is the iron pillar at Delhi. While there are many large works of ancient times in metal, for example the Colossus of Rhodes, the gigantic statues of the Buddhists, and others, these were of brass or copper, all of them hollow and built up of pieces riveted together, whereas the Pillar of Delhi is a solid shaft of wrought iron, upward of 16 inches in diameter and 22 feet in length, welded together, although the welding is not altogether perfect. In any case, it was a very creditable piece of work for a metallurgist of at least 1,600 years ago. At one time, owing to its peculiar color or hue, it was thought to be of "mixed metal," or even bronze, this belief probably arising from the curious yellow appearance of the upper part of the shaft, which Cunningham says he himself observed.

He adds that he obtained a small fragment from the rough lower part of the pillar, which was submitted to Dr. Murray Thompson, of the College at Roorkee, for analysis, who informed him that the metal was "pure malleable iron of 7.66 specific gravity." Practically pure iron (99.87 per cent iron) has a specific gravity of 7.8477. Therefore, the material of this pillar could not have been pure. Probably it was a somewhat inferior type of wrought iron, permeated with slag, and high in phósphorus, like the Sinhalese specimens described by the author in this paper. Pure iron, having the specific gravity mentioned, would weigh 490 pounds per cubic foot; the Delhi Pillar, with 7.66 specific gravity, would weigh 477 pounds per cubic foot.

Cunningham points out that, in true Eastern language and hyperbole, the inscription upon the pillar says that "The pillar is called the arm of fame of Raja Dhang, and the letters cut upon it are equal to the deep cuts inflicted upon his enemies by his sword writing his immortal fame."

The actual date of its first appearance is probably about A. D. 300. According to tradition, this pillar was erected by "Bilan Deo," or Anang Pal, the founder of the Tomara dynasty, who was assured by a learned Brahmin that the foot of the pillar had been driven so deep into the ground that it rested on the head of Vasuki, King of the Serpents, who supports the earth. But the Rajah doubted the truth of the Brahmin's statement, ordered the pillar to be dug up, when the foot of it was found to be wet with the blood of the Serpents' King, whose head it had pierced. Regretting his unbelief, the iron pillar was again raised, but owing to the King's former incredulity, every plan now failed in fixing it firmly, and in spite of all his efforts it still remained loose in the ground. This is said to be the origin of the name of the ancient city of Delhi which, signifies "unstable."

The Committee of the Iron and Steel Institute, in about the third year after its formation (1872, vol. ii., page 156), made some special inquiries with regard to this pillar. It appears that Lieut. Spratt, of the Royal Engineers, then stationed at Delhi, stated the height of the column above the ground to be 24 feet, and the depth below ground 3 feet. He said that the column or pillar ends in a bulb like an onion, which is held in place by eight short thick rods of iron, on which it rests, and which at their lower extremity are let into blocks of stone, in which they are secured by lead. The iron of which the pillar is made seems to have been originally in blooms of about 80 pounds weight each.

An excellent paper by Mr. Vincent A. Smith, M.R.A.S., Indian Civil Service, "On the Iron Pillar at Delhi (Mihrauli), and the Emperor Candra (Chandra)," appeared in the Royal Asiatic Society's Proceedings of 1897.

There are several important inscriptions upon the pillar, a full translation of which appears in Smith's paper above mentioned. These, notwithstanding the long exposure to wind and rain, are reported to be quite clear and sharp, as if no alteration had taken place since the pillar was first made and erected.

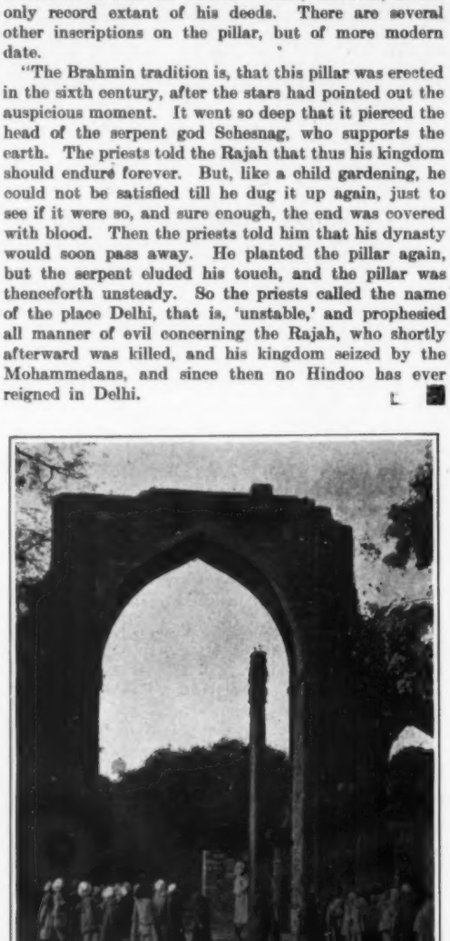
It is stated that these iron pillars were probably used owing to the belief in the special power of this metal to counteract demoniacal influence.

Miss Gordon Cumming, in her book, "In the Himalayas and on the Indian Plains," says: "I must first tell you about an extraordinary iron pillar, which stands near the base of the Kootub, and to which the city owes its modern name. It stands 22 feet above ground; some have declared its base is 26 feet below ground; others maintain it only extends a few feet, and terminates in a bulb like a turnip." The latter was later on found to be correct, the exact dimensions of the pillar being: total length, 23 feet 8 inches, of which 22 feet are above and only 20 inches below ground; the upper diameter is 12½ inches, the lower diameter 16½ inches; the total weight is about 6 tons.

Sir Alexander Cunningham's statement that the length was not less than 60 feet, was apparently based upon incorrect data.

Miss Cumming goes on to say: "It is wrought like our finest metal, and shows no symptoms of rust, though it has stood here for many centuries. It bears an inscription in Sanscrit, describing it as the 'triumphal pillar of Rajah Dhava, A. D. 310, who wrote his immortal fame with his sword.' This, however, is the only record extant of his deeds. There are several other inscriptions on the pillar, but of more modern date.

"The Brahmin tradition is, that this pillar was erected in the sixth century, after the stars had pointed out the auspicious moment. It went so deep that it pierced the head of the serpent god Schesnag, who supports the earth. The priests told the Rajah that thus his kingdom should endure forever. But, like a child gardening, he could not be satisfied till he dug it up again, just to see if it were so, and sure enough, the end was covered with blood. Then the priests told him that his dynasty would soon pass away. He planted the pillar again, but the serpent eluded his touch, and the pillar was thenceforth unsteady. So the priests called the name of the place Delhi, that is, 'unstable,' and prophesied all manner of evil concerning the Rajah, who shortly afterward was killed, and his kingdom seized by the Mohammedans, and since then no Hindoo has ever reigned in Delhi.



The Iron Pillar at Delhi.

"Nevertheless, the pillar is now firm as a rock, and has even resisted the cannon of Nadir Shah, who purposely fired against it. The marks of the cannon balls are clear enough. Hindoos believe that so long as this column stands the kingdom has not finally passed from them."

In a photograph taken many years ago no stone base or pedestal appears; moreover, the stones in the neighborhood of the pillar have been disturbed. This, no doubt, was caused by those who excavated to see the depth of the pillar below the surface of the ground. This, it appears, was carried out in 1871 by Mr. Beglar. The photograph shows an interesting group of natives examining the pillar. The stone base appears to have afterward been put in order.

The iron pillar at Dhār or Dhāra (the ancient capital of Malava, and 33 miles west of Indor), which was described by Mr. Smith in a paper to the Royal Asiatic Society in 1898, had a total length of no less than 42 feet. This is specially interesting, owing to its extraordinary length. The three existing pieces measure 24 feet, 12 feet, and 6 feet in length, aggregating 42 feet, in addition to a missing fragment, so that if these figures are correct, the column is approximately double the height of the Delhi pillar.

Mr. Smith rightly says: "While we marvel at the skill shown by the ancient artificers in forging the great mass of the Delhi pillar, we must give a still greater measure of admiration to the forgotten craftsmen who dealt so successfully in producing the still more ponderous iron mass of the Dhār pillar monument, with its total length of 42 feet, which, like the pillar at Delhi, is of the Gupta period, or about the year 321 of our Christian era."

There are also in existence in India several very large iron girders at Puri, ornamental iron gates of ancient origin at Somnali, and a wrought-iron gun, said to be 24 feet in length, at Nuwiri.

The author has given a detailed description of these two pillars, as they form the only known ancient large masses of iron in the world, so that they are indeed remarkable. But little more than a generation has elapsed since objects of this size and weight were made possible, even in our time.

V.

REMARKS BY MESSRS. OSMOND AND MASPÉRO.

The author has shown elsewhere in this paper that the ancient specimens now examined cannot be termed "steel"—that is, in the true sense of the word. They are practically wrought iron, though, as evidenced in the chisel, there is distinct proof that the edges of this specimen have been submitted to a carburizing or cementation process of some kind. In this sense, therefore, the chisel may be termed "steel"—at any rate as regards such edges.

Moreover, if the art of cementing or steelifying articles of iron was known and understood, then with such knowledge it would be quite possible to produce tools possessing excellent qualities, as the cutting edges could then be hardened by water quenching. If this was so, as appears to be the case, then we can readily understand how the works of stone were executed in Egypt.

While upon this point, reference may be made to some interesting correspondence the author has had with Mr. F. Osmond, the eminent French metallurgist. Some time ago the author asked Mr. Osmond if he knew of any specimens of ancient iron and steel in existence, and also whether he knew of any evidence in France as to the ancient Egyptians using iron and steel tools. He was, however, unable to point to such evidence, but made some inquiries in other directions, with the following result:

These remarks by Mr. Osmond appear to be worthy of giving in full, because they have a most important bearing upon the question of the use of iron and steel by the ancient Egyptians. Moreover, they probably prove that the nature of the material used by the Egyptians was iron of similar quality to that found in the ancient Sinhalese specimens obtained from the Colombo Museum, and upon which the present research has been carried out.

Mr. Osmond communicated with the well-known Egyptologist, Mr. Maspéro, in Egypt, that, in reference to a note he (Mr. Osmond) had presented to the Academy on bronze work of prehistoric times, Prof. Riban, of the Sorbonne, stated he understood that during certain conversation at a personal meeting between Mr. Maspéro, when he was in Paris, and Mr. Berthelot, that he (Mr. Maspéro) had referred to the granite-cutting work of the ancient Egyptians. Mr. Riban understood that Mr. Maspéro had then said that antique paintings or drawings existed, and that these showed each stone-cutter had assistants at his side, whose business it was to repair or sharpen his tools. From this it appeared that possibly tempered steel was not then in use, and that tools were employed made of iron or bronze.

Mr. Osmond then pointed out to Mr. Maspéro that he had received reproductions of paintings extracted from *Monuments de l'Egypte et de la Nubie d'apres les dessins executes sur les lieux sous la direction de Champollion le jeune* (Paris, 1845, Firman Didot), which he thought showed that there were sculptors and stone-cutters who did not appear to have assistants to repair their tools.

Mr. Osmond then asked Mr. Maspéro the following questions:

"Where are the originals showing the stone-cutters with assistants? If there are any reproductions, where can they be found? Are the paintings or drawings showing the stone-cutters with assistants anterior to those reproduced by Champollion? If this were the case, it might be possible to fix the date of the introduction of tempered steel into Egypt.

"I have been induced to investigate these questions by my friend Sir Robert Hadfield, Fellow of the Royal Society of London, who has recently obtained some interesting ancient specimens and documents relating to iron and steel production in Ceylon."

In reply, Mr. Maspéro wrote (March, 1911) that he had been unable to answer Mr. Osmond's letter until after his return to Cairo. The following are Mr. Maspéro's own words, which, being so interesting, are quoted *in extenso:*

"I was unable to answer your letter until after my return to Cairo, which occurred only a few days ago. This is briefly what there is to be said on the subject:

"1. Mr. Riban did not gather what I said to M. Berthelot quite accurately; I was speaking of experiences of mine about 1884 and 1885 at Luxor. In order to obtain an insight into the technique of the Egyptian sculptors, I ordered from a native copyist of great ability a granite statue in Egyptian style. Being present during the production of this statue, I observed that the workman used for cutting the stone, points of soft iron with wooden handles. He had some fifty of

these at his disposal, which he placed in the handle as he needed them. Each point became softened after three or four mallet strokes at the most. He then threw this away, took another, and an assistant put the softened points in the fire and then hammered them out to put a new head on them. The statue was made—or rather the bust, for it only represented a half-figure—in about three weeks, all the work being done practically, as one might say, by wearing out the iron and then restoring its point by forging. By being hammered this point became very hard.

"In the monuments there are no representations where a sculptor is to be found with appliances of this kind. It is the modern usage, and by examining the bronze points and chisels in our museums the idea was suggested to me which I have just called to your attention, and of which I spoke to Mr. Berthelot.

"2. There is nothing either on the monuments or in the museums to indicate that the Egyptians used, or even knew of, hardened steel."

As an observation on the above, the author would point out that the ancient Sinhalese specimens now described—at any rate as regards the chisel—show distinct signs of cementation, so that a pointed chisel, by being heated for some time in the smith's hearth, or in some other manner, might become carburized, and therefore much harder at the point even if it was not quenched. It would therefore seem, from the antiquity of the specimens which were obtained by the author from the Colombo Museum, that at any rate at least 1,400 years ago, chisels of iron, apparently with carburized or cemented edges, were known and in use. It is, therefore, very probable that the same knowledge existed in Egypt.

VI.

HARDNESS RETENTIVITY OF ANCIENT SPECIMENS OF IRON AND STEEL.

The retention of the hardness of ancient specimens of iron and steel is dealt with by Dr. Cecil H. Desch in his recent interesting work on Metallography.

Dr. Desch speaks of the phases retained by quenching being commonly spoken of as metastable. He considered, however, that while experimental proof had not been produced, we were bound to assume that the metastable limit had been passed, and that the systems are correctly described as labile, not as metastable. Quenched specimens therefore tend spontaneously to assume an equilibrium condition by undergoing the transformation which was suppressed by quenching. It is uncertain how far the spontaneous change can proceed at ordinary temperatures. White tin, which is only stable above 18 degrees, does not change into gray tin at 0 degree unless brought into contact with the new phase. Below 0 degree the change can occur spontaneously, although even at low temperatures it may fail to occur when the tin is kept for long periods. This would seem to indicate that the metastable limit for tin lies much below 0 degree.

Dr. Desch considers that hardened steel is undoubtedly labile at the ordinary temperature; and the presence of the stable phase is not necessary to initiate change. But there is little evidence that softening of steel takes place spontaneously unless the temperature is raised. He also states that Japanese swords of the fifteenth century, when carefully preserved, are found to be as hard at the edge as if newly hardened; it would therefore seem that no appreciable return to the stable state takes place in the course of several centuries at atmospheric temperatures. On the other hand, prolonged heating of hardened steel, even at 100 degrees, produces an appreciable softening, and heating at 150 degrees, in a few minutes. The whole question of labile and metastable conditions in undercooled solid alloys demands fuller investigation.

The above statement by Dr. Desch is particularly interesting in regard to the present paper, because it shows that material of ancient origin, although found in soft condition, may really have originally been quite hard. Thus, the edge of the ancient chisel, described in Experiment No. 2252, distinctly shows a defined structure in certain parts, differing from the other portion, apparently martensitic, as if it had once been in the hardened condition, but by the efflux of time had gradually assumed the condition in which it was now found—that is, soft. On the other hand, this particular chisel may not have been hardened, although the micro-structure, by the presence of troostite, seems to indicate that this may have once been the case. It is impossible to reach any sure conclusion on this point.

(To be continued.)

Luminescence Analysis*

A New Test for Chemicals With the Aid of Violet Light

THE long history of science is filled with instances of phenomena noted at first only for their beauty or mystery, which have later proved to be of immense practical value to mankind. A new example of this is the striking phenomenon of luminescence, which has recently been made the means of a method of analysis of the utmost delicacy and applicable to a great variety of substances, such as minerals, chemicals for commercial, technical, or laboratory use, food stuffs, etc.

It is a well-known fact that most bodies display luminescence under the influence of the ultra-violet rays. The term includes both fluorescence and phosphorescence. The name fluorescence is applied to the glow visible only during the action of the rays, and instantly disappearing when they are withdrawn, while phosphorescence is a luminescence accompanied by an after-glow of longer or shorter duration. Furthermore, *luminescence* signifies the so-called "cold light," in contradistinction to that coming from the heating of bodies and accompanied by heat rays.

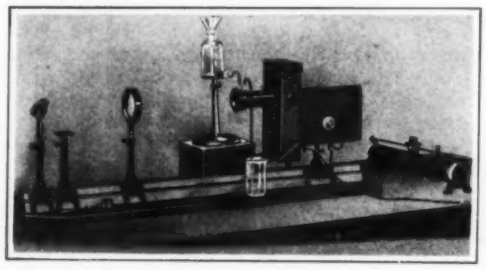
Although nearly all bodies fluoresce under the action of the ultra-violet rays, they exhibit different shades and intensities of color. This can be very prettily shown by a number of experiments, some of which will be mentioned later, and it is on this fact, of course, that the methods of analysis have been based.

The two great difficulties to be overcome were, firstly, that of securing a sufficiently intense source of ultra-violet rays, and secondly, that of properly separating these rays from the accompanying rays of light and heat, which would tend to obscure and vitiate results.

Many lights are known which are rich in ultra-violet rays, such as the arc light, mercury-lamp and the mercury-vapor light, the "uviol" light, the quartz lamp, but the one found best in practice is the ferro-carbon arc light. This is an ordinary electric arc light whose carbons have been impregnated with iron salts. It is burned at about 3 to 10 amperes and is shielded from all outside light by an impervious cover. On this cover is an extensible tube containing two small collector lenses; and at the end of the tube is a very ingenious and perfect filter for excluding all rays other than the ultra-violet.

The separation, or "filtering" of light rays can be accomplished either by dispersion or by absorption. The first consists in the spreading apart of the rays by means of a prism, which is made possible by reason of their varying refractive power. The visible rays can then be cut off by a shutter or blind, leaving only the ultra-violet rays required. This method has two serious disadvantages, one the great diminution in intensity, and the other difficulty found in practice of avoiding a small intermixture of visible light-rays.

Hence, the absorption method of filtering out the undesired rays by means of suitable intervening media has been found preferable. It has long been known, of course, that certain transparent media, such as panes of glass, sheets of gelatine, and various fluids would allow one kind of light to pass, such as red or green, while excluding others. It was, therefore, a natural conclusion and one quickly verified, that similar media existed which would be pervious to ultra-violet rays, while excluding visible rays. Thus Prof. Straubel suggested a thin silver film which permits the



General View of the Apparatus.

passage of a very narrow strips of the spectrum, about 320$\mu\mu$. This filter is much used in astro-physical researches. Again, the American physicist, Wood, constructed a filter which permits the passage in general only of very short waves of light, but the intensity is low, and there seems an unavoidable admixture of visible light.

Both these filters, therefore, are unsuited for the delicate purposes of luminescence analysis. The desired object, however, has been attained by a clever combination of filters made by Prof. Lehmann of Jena. In its construction are used, firstly, the yellow dye-stuff, nitrosodimethylanilin recommended by Wood; this absorbs the blue rays, but is quite permeable to the ultra-violet rays of a wave-length of 400 to 300$\mu\mu$. To eliminate the green and bright-red rays a plate of the Jena blue-uviol glass invented by Dr. Zschimmer is employed. This blue-colored glass allows the passage besides blue rays, of the ultra-violet up to 300$\mu\mu$. Hence, by the combination of these two we have a filter which allows the transmission of the ultra-violet from 300 to 400$\mu\mu$ very satisfactorily. But the combination is still transparent to the eye for the dark-red rays and for heat-rays. To obviate this use is made of an aqueous solution of copper sulphate.

The filter as prepared for Dr. Lehmann by the Zeiss Works consists of a cell with walls of blue uviol glass. To one of the outer walls is applied a thin gelatine film colored with nitrosodimethylanilin; this is protected by a second plate of the uviol glass. The cell is now filled with a 20 per cent solution of copper sulphate. When the lamp is burned with more than 5 amperes it is necessary to cool the filter, and this Lehmann accomplishes by the simple expedient of allowing the copper sulphate to flow through the filter in a slow stream. This arrangement is shown in the illustration. On the optical bench on which the lamp is placed stands also a large quartz-lens which serves to condense the ultra-violet rays emitted by the lamp upon a smaller surface and thus create a spot of intense light in which very small objects can be examined. A small adjustable plate or "table" serves for the convenient holding of the preparations. Furthermore, a small mirror is set up to throw the light from above downward on this "table" when it is a question of illuminating horizontal surfaces.

This apparatus permits the demonstration of some very striking effects of fluorescence. If the room be darkened and the ultra-violet light thrown on a porcelain plate and a screen of white paper, the latter will shimmer with a blue-white radiance while the porcelain will appear as if covered over with black satin; the contrast is still more striking if one side of the paper be coated with luminous paint.

The physiological effects are particularly curious and even startling in these rays. The hands, and especially the nails gleam with a ghostly bluish-white. The teeth and the whites of the eyes are strongly luminous and the lenses of the eyes even more so. This, except in case of the teeth is due to *keratin* contained in these tissues. Both natural and artificial rubies show up well unless too dark in tone. Fluorspar is very effective, glowing with an intense blue.

Many bodies show discontinuous spectra in fluorescence. This is markedly true of a large number of compounds of the aromatic series, as shown by Prof. Goldstein. The compounds anthracene, fluorene, and chrysogen are strongly fluorescent. To prove the discontinuity of the fluorescence spectra to large audiences Lehmann made use of the *telespectroscope*, an instrument manufactured by the Zeiss works for the purpose of permitting from the auditorium the close observation of *points* of light, such as Bunsen flames, electric sparks, and luminescent objects of small size.

Minerals apparently homogeneous under the ultra-violet rays often display specks or streaks of foreign substances, glowing with a different light. The same thing is true of chemicals. Experiments are now being conducted along these lines. It is even stated that the same crystals from different localities show very different luminous appearances; such being especially the case with fluorspar, limespar, aragonite, etc.

Another important application of ultra-violet light is its use in connection with the ultramicroscope. We may thank Dr. Köhler for the introduction of this light into microphotography. But a difficulty immediately became apparent, since not only the objects to be examined—such as bacteria, animal and vegetable tissues, minerals, etc.—were fluorescent, but also the lenses of the objective, so that the object, of course, was imperceptible. Hence, it must be managed so that the ultra-violet rays strike the object and not the lenses. This was achieved by Dr. Heimstädt by the use of the dark-field long used in the so-called ultramicro-

* The article here presented is based on a paper read by Prof. Lehmann, and published in the *Zeitschrift für angewandte Chemie*; also on an article by Dr. Heinstadt in the *Zeitschift für wissenschaftliche Mikroscopie*.

scope. By a simple device the rays, which form the central sheaf, are shut off, so that the rays fall only at the side of the object. These reach the object then only by means of refraction in the medium and reflection on the cover-glass. The object throws back this light, and the appearance thus produced can be examined in the microscope, thus it is not the particle itself, but the light from it that is seen. In this manner, it is claimed, excessively small particles can be demonstrated, though they remain invisible even under the most powerful lens, because of their minuteness.

This florescence microscope is now constructed by the firm of C. Reich in Vienna. The filter is practically the same as the one invented by Lehmann, except that the nitrosodimethylanilin is used in a solution of 1/20,000 inclosed between glass plates. The emergent rays must fill the three-sided quartz condensor of the microscope. This is tested by a leaf of white tissue paper, which glows blue-white in the light. In the condensor is placed the diaphragm, which shuts off the central portion of the light-pencil. The holder for the object must be made of quartz or uviol glass since ordinary glass absorbs the ultra-violet rays. The object must, of course, lie in a medium transparent to the rays, and with an exponent of refraction greater than 1. Specially adapted are distilled water, glycerine, "normal" salt solution, potash solution, etc. The cover-glass can be of ordinary glass, but in the most delicate researches quartz is better. The ordinary objective and ocular can be used, but the use of an apochromatic system, together with a compensating ocular, is better. The objects glow in the light peculiar to them against a dark gray back ground. The different kinds of bacteria have definite appearances. Many things show more clearly than in the ordinary microscope.

Doubtless, this new means of research will yield a rich harvest to patient investigators in many fields.

It should be remarked regarding the filter, that this is non-transparent to the eye, but it causes an impression of bluish gray to the eye, owing to the excitement of the retina by the longer ultra-violet rays, and the fluorescence of the ocular media.

The Nature, Origin and Maintenance of Life—III

Inaugural Address of the President of the British Association for the Advancement of Science

By Prof. E. A. Shäfer, LL.D., D.Sc., M.D., F.R.S.

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 1919, Page 227, October 12, 1912

REGULATION OF BODY TEMPERATURE.

And by the action of the nervous system upon the skin glands, together with its effect in increasing or diminishing the blood supply to the cutaneous blood vessels, the temperature of our blood is regulated and is kept at the point best suited for maintenance of the life and activity of the tissues.

EFFECTS OF EMOTIONS ON SECRETION.

The action of the nervous system upon the secretion of glands is strikingly exemplified, as in the case of its action upon the heart and blood vessels by the effects of the emotions. Thus an emotion of one kind —such as the anticipation of food—will cause saliva to flow—"the mouth to water"; whereas an emotion of another kind—such as fear or anxiety—will stop the secretion, causing the "tongue to cleave unto the roof of the mouth," and rendering speech difficult or impossible. Such arrest of the salivary secretion also makes the swallowing of dry food difficult; advantage of this fact is taken in the "ordeal by rice" which used to be employed in the East for the detection of criminals.

REGULATION BY CHEMICAL AGENTS: HORMONES.—INTERNAL SECRETIONS.

The activities of the cells constituting our bodies are controlled, as already mentioned, in another way than through the nervous system, viz., by chemical agents (hormones) circulating in the blood. Many of these are produced by special glandular organs, known as internally secreting glands. The ordinary secreting glands pour their secretions on the exterior of the body or on a surface communicating with the exterior; the internally secreting glands pass the materials which they produce directly into the blood. In this fluid the hormones are carried to distant organs. Their influence upon an organ may be essential to the proper performance of its functions or may be merely ancillary to it. In the former case removal of the internally secreting gland which produces the hormone, or its destruction by disease, may prove fatal to the organism.

SUPRARENALS.

This as the case with the suprarenal capsules: small glands which are adjacent to the kidneys, although having no physiological connection with these organs. A Guy's physician, Dr. Addison, in the middle of the last century showed that a certain affection, almost always fatal, since known by his name, is associated with disease of the suprarenal capsules. A short time after this observation a French physiologist, Brown-Séquard, found that animals from which the suprarenal capsules are removed rarely survive the operation for more than a few days. In the concluding decade of the last century interest in these bodies was revived by the discovery that they are constantly yielding to the blood a chemical agent (or hormone) which stimulates the contractions of the heart and arteries and assists in the promotion of every action which is brought about through the sympathetic nervous system (Langley). In this manner the importance of their integrity has been explained, although we have still much to learn regarding their functions.

THYROID.

Another instance of an internally secreting gland which is essential to life, or at least to its maintenance in a normal condition, is the thyroid. The association of imperfect development or disease of the thyroid with disorders of nutrition and inactivity of the nervous system is well ascertained. The form of idiocy known as cretinism and the affection termed myxœdema are both associated with deficiency of its secretion; somewhat similar conditions to these are produced by the surgical removal of the gland. The symptoms are alleviated or cured by the administration of its juice. On the other hand, enlargement of the thyroid, accompanied by increase of its secretion, produces symptoms of nervous excitation, and similar symptoms are caused by excessive administration of glandular substance by the mouth. From these observations it is inferred that the juice contains hormones which help to regulate the nutrition of the body and serve to stimulate the nervous system, for the higher functions of which they appear to be essential. To quote M. Gley, to whose researches we owe much of our knowledge regarding the functions of this organ: "La genèse et l'exercise des plus hautes facultés de l'homme sont conditionnés par l'action purement chimique d'un produit de sécrétion. Que les phychologues méditent ces faits!"

PARATHYROIDS.

The case of the parathyroid glandules is still more remarkable. These organs were discovered by Sandström in 1880. They are four minute bodies, each no larger than a pin's head, imbedded in the thyroid. Small as they are, their internal secretion possesses hormones which exert a powerful influence upon the nervous system. If they are completely removed, a complex of symptoms, technically known as "tetany," is liable to occur, which is always serious and may be fatal. Like the hormones of the thyroid itself, therefore, those of the parathyroids produce effects upon the nervous system, to which they are carried by the blood; although the effects are of a different kind.

PITUITARY.

Another internally secreting gland which has evoked considerable interest during the last few years is the pituitary body. This is a small structure no larger than a cob-nut attached to the base of the brain. It is mainly composed of glandular cells. Its removal has been found (by most observers) to be fatal—often within two or three days. Its hypertrophy, when occurring during the general growth of the body, is attended by an undue development of the skeleton, so that the stature tends to assume gigantic proportions. When the hypertrophy occurs after growth is completed, the extremities—viz., the hands and feet, and the bones of the face—are mainly affected; hence the condition has been termed "acromegaly" (enlargement of extremities). The association of this condition with affections of the pituitary was pointed out in 1885 by a distinguished French physician, Dr. Pierre Marie. Both "giants" and "acromegalists" are almost invariably found to have an enlarged pituitary. The enlargement is generally confined to one part—the anterior lobe—and we conclude that this produces hormones which stimulate the growth of the body generally and of the skeleton in particular. The remainder of the pituitary is different in structure from the anterior lobe and has a different function. From it hormones can be extracted which, like those of the suprarenal capsule, although not exactly in the same manner, influence the contraction of the heart and arteries. Its extracts are also instrumental in promoting the secretion of certain glands. When injected into the blood they cause a free secretion of water from the kidneys and of milk from the mammary glands, neither of which organs are directly influenced (as most other glands are) through the nervous system. Doubtless under natural conditions these organs are stimulated to activity by hormones which are produced in the pituitary and which pass from this into the blood.

The internlly secreting glands which have been mentioned (thyroid, parathyroid, suprarenal, pituitary) have, so far as is known, no other function than that of producing chemical substances of this character for the influencing of other organs, to which they are conveyed by the blood. It is interesting to observe that these glands are all of very small size, none being larger than a walnut, and some—the parathyroids—almost microscopic. In spite of this they are essential to the proper maintenance of the life of the body, and the total removal of any of them by disease or operation is in most cases speedily fatal.

PANCREAS.

There are, however, organs in the body yielding internal secretions to the blood in the shape of hormones, but exercising at the same time other functions. A striking instance is furnished by the pancreas, the secretion of which is the most important of the digestive juices. This—the pancreatic juice—forms the external secretion of the gland, and is poured into the intestine, where its action upon the food as it passes out from the stomach has long been recognized. It was, however, discovered in 1889 by von Mering and Minkowski that the pancreas also furnishes an internal secretion, containing a hormone which is passed from the pancreas into the blood, by which it is carried first to the liver and afterward to the body generally. This hormone is essential to the proper utilization of carbohydrates in the organism. It is well known that the carbohydrates of the food are converted into grape sugar and circulate in this form in the blood, which always contains a certain amount the blood conveys it to all the cells of the body, and they utilize it as fuel. If, owing to disease of the pancreas or as the result of its removal by surgical procedure, its internal secretion is not available, sugar is no longer properly utilized by the cells of the body and tends to accumulate in the blood; from the blood the excess passes off by the kidneys, producing diabetes.

DUODENUM.

Another instance of an internal secretion furnished by an organ which is devoted largely to other functions in the "pro-secretin" found in the cells lining the duodenum. When the acid gastric juice comes into contact with these cells it converts their pro-secretin into "secretin." This is a hormone which is passed into the blood and circulates with that fluid. It has a specific effect on the externally secreting cells of the pancreas, and causes the rapid outpouring of pancreatic juice into the intestine. This effect is similar to that of the hormones of the pituitary body upon the cells of the kidney and mammary gland. It was discovered by Bayliss and Starling.

INTERNAL SECRETIONS OF THE REPRODUCTIVE ORGANS.

The reproductive glands furnish in many respects the most interesting example of organs which—besides their ordinary products, the germ and sperm cells (ova and spermatozoa)—form hormones which circulate in the blood and effect changes in cells of distant parts of the body. It is through these hormones that the secondary sexual characters, such as the comb and tail of the cock, the mane of the lion, the horns of the stag, the beard and enlarged larynx of a man, are produced, as well as the many differences in form and structure of the body which are characteristic of the sexes. The dependence of these so-called secondary sexual characters upon the state of development of the reproductive organs has been recognized from time immemorial, but has usually been ascribed to influences produced through the nervous system, and it is only in recent years that the changes have been shown to be brought about by the agency of internal secretions and hormones, passed from the reproductive glands into the circulating blood.

CHEMICAL NATURE OF HORMONES.

It has been possible in only one or two instances to prepare and isolate the hormones of the internal secretions in a sufficient condition of purity to subject them to analysis, but enough is known about them to indicate that they are organic bodies of a not very complex nature, far simpler than proteins and even than enzymes. Those which have been studied are all dialysable, are readily soluble in water, but insoluble in alcohol, and are not destroyed by boiling. One at least—that of the medulla of the suprarenal capsule—has been prepared synthetically, and when their exact chemical nature has been somewhat better elucidated it will probably not be difficult to obtain others in the same way.

From the above it is clear that not only is a co-ordination through the nervous system necessary in order that life shall be maintained in a normal condition, but a chemical co-ordination is no less essential. These may be independent of one another; but, on the other hand, they may react upon one another. For it can be shown that the production of some at least of the hormones is under the influence of the nervous system (Biedl, Asher, Elliott); while, as we have seen, some of the functions of the nervous system are dependent upon hormones.

PROTECTIVE CHEMICAL MECHANISMS.—TOXINS AND ANTITOXINS.

Time will not permit me to refer in any but the briefest manner to the protective mechanisms which the cell-aggregate has evolved for its defense against disease, especially disease produced by parasitic micro-organisms. These, which belong with few exceptions to the Protista, are without doubt the most formidable enemies which the multicellular Metazoa, to which all the higher animal organisms belong, have to contend against. To such micro-organisms are due, *inter alia*, all diseases which are liable to become epidemic, such as anthrax and rinderpest in cattle, distemper in dogs and cats, smallpox, scarlet fever, measles, and sleeping sickness in man. The advances of modern medicine have shown that the symptoms of these diseases—the disturbances of nutrition, the temperature, the lassitude or excitement, and other nervous disturbances—are the effects of chemical poisons (*toxins*) produced by the micro-organisms and acting deleteriously upon the tissues of the body. The tissues, on the other hand, endeavor to counteract these effects by producing other chemical substances destructive to the micro-organisms or antagonistic to their action; these are known as *anti-bodies*. Sometimes the protection takes the form of a subtle alteration in the living substance of the cells which renders them for a long time, or even permanently, insusceptible (immune) to the action of the poison. Sometimes certain cells of the body, such as the white corpuscles of the blood, eat the invading micro-organisms and destroy them bodily by the action of chemical agents within their protoplasm. The result of an illness thus depends upon the result of the struggle between these opposing forces—the micro-organisms on the one hand and the cells of the body on the other—both of which fight with chemical weapons. If the cells of the body do not succeed in destroying the invading organisms, it is certain that the invaders will in the long run destroy them, for in this combat no quarter is given. Fortunately we have been able, by the aid of animal experimentation, to acquire some knowledge of the manner in which we are attacked by micro-organisms and of the methods which the cells of our body adopt to repel the attack, and the knowledge is now extensively utilized to assist our defense.

PARASITIC NATURE OF DISEASES.

For this purpose protective serums or antitoxins, which have been formed in the blood of other animals, are employed to supplement the action of those which our own cells produce. It is not too much to assert that the knowledge of the parasitic origin of so many diseases and of the chemical agents which on the one hand cause, and on the other combat, their symptoms, has transformed medicine from a mere art practised empirically into a real science based upon experiment. The transformation has opened out an illimitable vista of possibilities in the direction not only of cure, but, more important still, of prevention. It has taken place within the memory of most of us who are here present. And only last February the world was mourning the death of one of the greatest of its benefactors—a former president of this association—who, by applying this knowledge to the practise of surgery, was instrumental, even in his own lifetime, in saving more lives than were destroyed in all the bloody wars of the nineteenth century!

SENESCENCE AND DEATH.

The question has been debated whether, if all accidental modes of destruction of the life of the cell could be eliminated, there would remain a possibility of individual cell life, and even of aggregate cell life, continuing indefinitely; in other words, Are the phenomena of senescence and death a natural and necessary sequence to the existence of life? To most of my audience it will appear that the subject is not open to debate. But some physiologists (e. g., Metchnikoff) hold that the condition of senescence is itself abnormal; that old age is a form of disease or is due to disease, and, theoretically at least, is capable of being eliminated. We have already seen that individual cell life, such as that of the white blood corpuscles and of the cells of many tissues, can under suitable conditions be prolonged for days or weeks or months after general death. Unicellular organisms kept under suitable conditions of nutrition have been observed to carry on their functions normally for prolonged periods and to show no degeneration such as would accompany senescence. They give rise by division to others of the same kind, which also, under favorable conditions, continue to live, to all appearance indefinitely. But these instances, although they indicate that in the simplest forms of organization existence may be greatly extended without signs of decay, do not furnish conclusive evidence of indefinite prolongation of life. Most of the cells which constitute the body, after a period of growth and activity, sometimes more, sometimes less prolonged, eventually undergo atrophy and cease to perform satisfactorily the functions which are allotted to them. And when we consider the body as a whole, we find that in every case the life of the aggregate consists of a definite cycle of changes which, after passing through the stages of growth and maturity, always leads to senescence, and finally terminates in death. The only exception is in the reproductive cells, in which the processes of maturation and fertilization result in rejuvenescence, so that instead of the usual downward change toward senescence, the fertilized ovum obtains a new lease of life, which is carried on into the new-formed organism. The latter again itself ultimately forms reproductive cells, and thus the life of the species is continued. It is only in the sense of its propagation in this way from one generation to another that we can speak of the indefinite continuance of life; we can only be immortal through our descendants!

AVERAGE DURATION OF LIFE AND POSSIBILITY OF ITS PROLONGATION.

The individuals of every species of animal appear to have an average duration of existence. Some species are known the individuals of which live only for a few hours, while others survive for a hundred years. In man himself the average length of life would probably be greater than the three-score and ten years allotted to him by the Psalmist if we could eliminate the results of disease and accident; when these results are included it falls far short of that period. If the terms of life given in the purely mythological part of the Old Testament were credible, man would in the early stages of his history have possessed a remarkable power of resisting age and disease. But, although many here present were brought up to believe in their literal veracity, such records are no longer accepted even by the most orthodox of theologians, and the nine hundred odd years with which Adam and his immediate descendants are credited, culminating in the nine hundred and sixty-nine of Methuselah, have been relegated, with the account of Creation and the Deluge, to their proper position in literature. When we come to the Hebrew patriarchs, we notice a considerable diminution to have taken place in what the insurance offices term the "expectation of life." Abraham is described as having lived only to 175 years, Joseph and Joshua to 110, Moses to 120; even at that age "his eye was not dim nor his natural force abated." We cannot say that under ideal conditions all these terms are impossible; indeed, Metchnikoff is disposed to regard them as probable; for great ages are still occasionally recorded, although it is doubtful if any as considerable as these are ever substantiated. That the expectation of life was better then than now would be inferred from the apologetic tone adopted by Jacob when questioned by Pharaoh as to his age: "The days of the years of my pilgrimage are a hundred and thirty years; few and evil have the days of the years of my life been, and have not attained unto the days of the years of the life of my fathers in the days of their pilgrimage." David, to whom, before the advent of the modern statistician, we owe the idea that seventy years is to be regarded as the normal period of life, is himself merely stated to have "died in a good old age." The periods recorded for the Kings show a considerable falling off as compared with the Patriarchs; but not a few were cut off by violent deaths, and many lived lives which were not ideal. Among eminent Greeks and Romans few very long lives are recorded, and the same is true of historical persons in mediæval and modern history. It is a long life that lasts much beyond eighty; three such linked together carry us far back into history. Mankind is in this respect more favored than most mammals, although a few of these surpass the period of man's existence. Strange that the brevity of human life should be a favorite theme of preacher and poet when the actual term of his "erring pilgrimage" is greater than that of most of his fellow creatures!

THE END OF LIFE.

The modern applications of the principles of preventive medicine and hygiene are no doubt operating to lengthen the average life. But even if the ravages of disease could be altogether eliminated, it is certain that at any rate the fixed cells of our body must eventually grow old and ultimately cease to function; when this happens to cells which are essential to the life of the organism, general death must result. This will always remain the universal law, from which there is no escape. "All that lives must die, passing through nature to eternity."

Such natural death unaccelerated by disease—is not death by disease as unnatural as death by accident?—should be quiet, painless phenomenon, unattended by violent change. As Dastre expresses it, "The need of death should appear at the end of life, just as the need of sleep appears at the end of the day." The change has been led gradually up to by an orderly succession of phases, and is itself the last manifestation of life. Were we all certain of a quiet passing—were we sure that there would be "no moaning of the bar when we go out to sea"—we could anticipate the coming of death after a ripe old age without apprehension. And if ever the time shall arrive when man will have learned to regard this change as a simple physiological process, as natural as the oncoming of sleep, the approach of the fatal shears will be as generally welcomed as it is now abhorred. Such a day is still distant; we can scarcely say that its dawning is visible. Let us at least hope that, in the manner depicted by Dürer in his well-known etching, the sunshine which science irradiates may eventually put to flight the melancholy which hovers, bat-like, over the termination of our lives, and which even the anticipation of a future happier existence has not hitherto succeeded in dispersing.

The Significance of Photo-Chemistry for the Theory of Vision*

By Prof. von Kries

THE theory that the action of light by which vision is produced is a chemical action is proably as old as our knowledge of the chemical effects of light in general. The theory was greatly strengthened by the invention of the art of photography, for no other organ of sense resembles any instrument made by man as closely as the eye resembles the photographer's camera, and it is only natural to carry the familiar comparison a step beyond the dioptric apparatus, and to regard the retina as the analogue of the photographic plate. This idea was advanced by Moser in 1842, but twenty years later, Helmholtz, in his classical "Physiologische Optik," asserted that it was yet impossible to decide whether light acts on the retina by producing chemical changes, heat or vibration. Within the next decade, however, Boll supplied a firm basis for the photochemical theory by the discovery that, in many animals, the retina slowly acquires in darkness a brilliant red color which is rapidly destroyed by exposure to daylight. This fact formed the starting point for the researches of Kuehne, who gave the name "visual purple," to the sensitive retinal pigment and proved that it could be bleached unequally in different parts of the retina, according to the local illumination produced by the formation of images of external objects. In this way Kuehne obtained ocular photographs, or "optograms," of the windows of the Heidelberg Institute. These results naturally attracted much attention, although it was evident that in the normal use of the eye the pigment would not be bleached sufficiently to produce visible optograms. The physiological function of the visual purple could not then be determinal, but Kuehne proved that its presence was not an indispensable condition for vision. Many years later, at the close of the last century, a definite physiological theory, which physiologists and ophthalmologists generally regard as highly probable, was formed. In connection therewith the physical and chemical properties of the visual purple have been successfully studied.

This physiological theory is based on a long known fact of microscopic anatomy. That layer of the retina which for various reasons is regarded as the part sensitive to light contains histological elements of two distinct types: the very slender and nearly cylindrical "rods" and the thicker, club-shaped "cones." The visual purple is found only in the external portions of the rods. Vision appears to depend on the activity of

* An abridgement of an address made before the German Bunsen Society, and published in the *Zeitschrift fuer Elektrochemie*.

both elements, rods and cones, either of which may preponderate or even act alone, according to circumstances. Ordinary vision, in full light, is accomplished by means of the cones, while the rods, which contain the visual purple, appear to provide for vision in dim light. It is assumed, furthermore, that the rods are absolutely color-blind and are affected only by difference in light and shade. The acuteness of vision in dim light is exceedingly variable. On entering a darkened room from full daylight, little or nothing can be seen until the eyes have slowly become adapted to the darkness. This familiar phenomenon may be explained by assuming that the sensitiveness of the rods is proportional to their content of visual purple, which is bleached and destroyed by light and slowly accumulates in darkness. The rods appears to possess an enormous measure, and the cones comparatively little, of this faculty of adaptation and change in sensitiveness.

The dependence of the effect of light upon its wave length is also very different in the two elements. In the prismatic spectrum of sunlight the maximum of brightness, for most eyes, lies in the reddish yellow, near the sodium or *D* line, but a feebly luminous spectrum appears, to an eye suitably adopted to darkness, as a colorless gray ribbon, which is brightest near the *E* line, in the (normally) green region. These two kinds of vision may be distinguished by the names "daylight vision" and "twilight vision", and the theory which recognizes the dual nature of the eye and its function may appropriately be called the duplex theory of vision.

This theory also furnishes a simple explanation of that peculiar variation in the apparent relative brightness of differently colored objects which has long been known as Purkinje's phenomenon. When red and blue objects are compared, first in bright daylight and then under gradually diminishing illumination, the maximum of apparent brightness continually shifts toward the blue, or shorter wave length, and the blue objects retain much of their color and luminosity after the red objects have become quite black. The explanation is that with diminishing illumination and progressive adaptation to darkness the rods gradually acquire a preponderance in vision, so that their maximum of brightness replaces that of the cones, which preponderate in full daylight.

In certain conditions each of these modes of vision can be isolated and studied separately. The central part of the retina, where vision is most distinct, contains no rods and is capable only of "daylight vision," i. e., vision in strong light. Its perception of dimly lighted objects is very little sharpened by long seclusion in darkness and Purkinje's phenomenon cannot be produced in this part of the retina. In the pathological condition known as hemeralopia or night blindness the whole retina lacks the power of "twilight vision." Persons so affected see very well in a good light but are almost blind in a dim light. On the other hand, persons who have been totally color-blind from birth possess "twilight vision" alone. They perceive differences in light and shade, but not in color, and their maximum of apparent brightness coincides with that of the "twilight vision" of normal eyes. The sight of the color-blind differs in no respect from that of normal persons, until a certain degree of brightness, which evidently represents the lower limit of excitability of the cones, is exceeded, when the "daylight vision," which the color-blind eye lacks, comes into play in the normal organ.

It may be asserted, therefore, that a perfectly definite part of the function of sight depends upon the visual purple, but that the most important and most perfect vision is entirely independent of it.

Kuehne extracted the visual purple by means of gall and aqueous solutions of gallates, and found that the pigment exhibited its characteristic color and sensitiveness to light, in solution as well as in the retina. No other solvent for it has yet been found. It is absolutely permanent in darkness; hence the action of light upon it is not, as it is in many cases, a mere acceleration of a process that goes on slowly in the dark. It is very improbable, furthermore, that the visual purple acts as an optical sensitizer to increase some other action of light and to bring into play otherwise ineffective wave lengths. In the totally color-blind no appreciable change in relative sensitiveness to different wave lengths, results from the accumulation of visual purple produced by seclusion in darkness. Hence, the physiological stimulus appears to depend directly upon the visual purple.

With the dependence of the action on the wave length, we come to the most interesting point in the photo-chemistry of the visual purple. Boll and Kuehne observed that this pigment is little or not at all affected by long waves. Koening found a maximum absorption of light near *F*, in the blue, and discovered the important fact, that the sensitiveness to light both in color-blind eyes and in "twilight vision," varies for different wave lengths, according to the law that governs the quantity of energy absorbed. In 1904 von Trendelenburg proved that the same law governs the chemical effect.

In other words, a given quantity of absorbed radiant energy, no matter what its wave length maybe, always produce the same bleaching effect upon the visual purple. A few years later Lasareff demonstrated the same law for many dye stuffs.

The visual purple is not directly bleached and destroyed by light, but is first transformed into a yellow pigment, which is practically re-converted into visual purple in darkness. A retina which has become yellow by exposure to light regains some of its purple hue in darkness, but in successive repetitions of the process the color gradually becomes fainter and finally vanishes.

Neither the nature of the chemical changes produced in the visual purple by light, nor the manner in which these changes effect physiological results, is yet known. The proportionality between chemical change and absorbed energy indicates a storing of radiant energy.

The "photo-chemical efficiency," or the fraction of the absorbed energy which is consumed in chemical work, varies exceedingly in different photochemical reactions. According to Warhig it is 46 per cent in the ozonizing of oxygen, and only 2 per cent in the decomposition of ammonia. Weigert deduces from Brown's observations a photochemical efficiency of nearly 100 per cent for the syntheses effected by chlorophyll under the influence of sunlight. The photochemical efficiency of the visual purple has not been determined.

No photochemical change is certainly known to occur in the cones which serve for "daylight vision." Differences in affinity for staining dyes, and other chemical changes are observed in the cones after exposure to light, but these effects may be due to physiological activity. Hence, in order to form an idea of the effect of light upon the cones, we are compelled to have recourse to the observable indirect or optical effects. Of these, the most remarkable are the dualistic phenomena of color sensation. This dualism is shown in two ways: by the fact that complimentary colors destroy each other, and by the fact that certain color sensations exclude each other. An object may appear at once red and yellow, but not red and green, or blue and yellow. Upon these long known phenomena of compatibility and contrast, Hering based his theory of complimentary colors, according to which the sensations red and green are produced by one pair, and the sensations yellow and blue by another pair, of oppositely directed processes. There is a temptation to connect this theory with the recently discovered fact, that light of different wave lengths may produce opposite chemical changes. Stobbe finds that long waves of light accelerate the reversal, occurring spontaneously in darkness, of a photochemical change produced by short waves, and Trautz has shown than many chemical processes are accelerated by some wave lengths and retarded by others. It should be remembered, however, that the action of light is confined to the retina, while visual sensations result from processes which take place in the cortex of the brain, in nerve cells which differ totally in structure from the retinal epithelium.

This is not the place to discuss the many obstacles encountered by Hering's theory, but one rock on which all dualistic theories of color perception appear to split may be pointed out. The assumption of opposite color sensations necessarily implies that these sensations are to some extent independent of the sensation of colorless brightness. The abnormalities of vision, the only field in which these assumptions can now be tested has furnished no evidence in favor of them. Hering's explanation of partial color-blindness as the result of a lack of the red-green sensation, is not supported by the observed facts, which rather indicate causes of another nature for this, and other abnormalities of vision.

All such conclusions, however, rest upon a very insecure foundation and it is not likely that we shall obtain any certain knowledge of the nature of the action of light upon the cones until the direct local effect has actually been observed. This is the task of physiologists and anatomists, but our knowledge of the changes which have already been observed in the visual purple of the rods can best be advanced by the photochemist. The peculiar perfection and adaptation to special purposes which is shown by many physical and chemical agencies and processes in living organisms is a fact of general theoretical interest. The photochemical efficiency of chlorophyll is a notable instance. The visual purple, therefore, may be recommended to the photochemist as a very promising object of study.

"Tempered Copper" Tools

ACCORDING to *The Engineering and Mining Journal*, 93, No. 20, 986, the copper-cutting instruments of the Tarascans, found in the Balsas River ruins in Guerrero, are so hard that they would turn the edge of a modern knife, and it has been claimed that these people, along with the Aztecs and Toltecs, possessed the secret of tempering copper. On the other hand, copper knives and axes, found at Atcopotzalco, are so soft that they can be cut with an ordinary pocket knife. Analysis showed that in all three localities the copper implements were of the same composition as the copper ores found therein. The blades from Guerrero, which are hard and apparently tempered, were made from the natural ore carrying nickel and cobalt, thus rendering the smelted alloy steel-like in hardness. Thus, the natural product gave an alloy of great hardness when heated and sharpened, while the other ores of practically pure copper, when smelted, resulted in implements which were soft and inferior in cutting value. The sharp cutting implements were, therefore, the result of Nature's handiwork, and it is indeed very questionable whether these people possessed the secret of tempering.

A Medium for Making Air Hose, etc., Tight, can be produced, according to *Chemiker Zeitung*, by mixing parts of pipe-clay, 10 parts of washed chalk, 1 part of English red, 20 parts of water and 1 part of talcum.

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SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

NEW YORK, SATURDAY, OCTOBER 19, 1912

Published weekly by Munn & Co., Inc. Charles Allen Munn, President; Frederick Converse Beach, Secretary and Treasurer; all at 361 Broadway, New York

Entered at the Post Office of New York, N. Y., as Second Class Matter

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The Scientific American Publications

Scientific American Supplement (established 1876). . per year $5.
Scientific American (established 1845) . . . . . " 3.
American Homes and Gardens . . . . . " 3.
The combined subscription rates and rates to foreign countries including Canada, will be furnished upon application.
Remit by postal or express money order, bank draft or check

Munn & Co., Inc., 361 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

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